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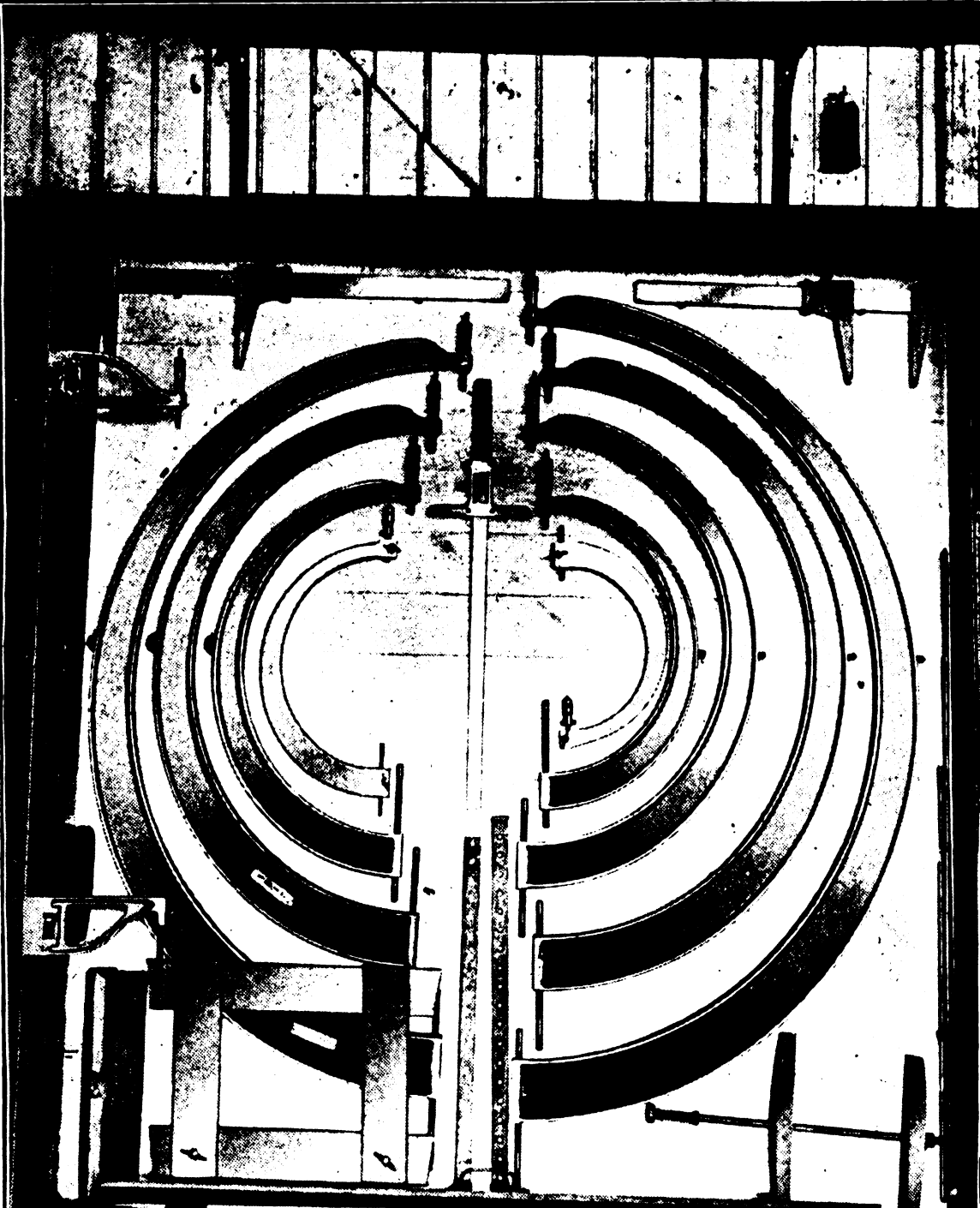
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Gages and gaging systems

Joseph Vincent Woodworth

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GAGES AND GAGING SYSTEMS

Gages and Gaging Systems

DESIGN, CONSTRUCTION AND USE OF TOOLS,
METHODS AND PROCESSES INVOLVED

A Treatise and Mechanics' Reference Work upon the Fundamentals, Principles, and Practices of Designing, Constructing, Using and Adapting Gages, Precision Instruments, Indicators, Squares, Verifying Tools, Test Measurement Instruments and Micrometers for Use in the Working of Metal Parts and the Reducing of Surfaces to Accurate Dimensions, Including Descriptions of the Value, Use and Installation of Gaging Systems, Tools for Manufacturing Mechanism, Testing Methods and Measurement Systems for Insuring the Production of Accurate Duplicate Parts and Interchangeability in the Modern Economic Manufacture of Precision Machinery, Tools, Punches, Dies and Accurate Repetition Parts of Metal

By JOSEPH V. WOODWORTH

Author of "*Grinding and Lapping, Tools, Methods and Processes*," "*Dies, Their Construction and Use*," "*Hardening, Tempering, etc., of Steel*," "*American Tool Making and Interchangeable Manufacturing*," "*Punches, Tools and Dies for Manufacturing in Presses*"



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PREFACE

THIS treatise is intended as a reference work and text-book for all practical men who are engaged in the manufacture of precision tools and interchangeable parts. It is hoped that all having to do with the manufacture of interchangeable work will find in these pages a comprehensive treatise on the design, construction, installation and use of the most modern gages and gaging systems that have been evolved in our best American shops.

Throughout the entire book it has been the aim to eliminate all obsolete practices and methods; and to confine the treatment exclusively to the design, construction, use and adaptation of the numerous tools and systems illustrated. It has further been the aim to make these descriptions as brief and concise as possible, and always of the most up-to-date and approved methods of construction, but never to the neglect of the fundamental principles involved.

While a number of the tools taken and methods described are original, the majority have been selected from the columns of the *American Machinist and Machinery*. The author, therefore, begs to extend his thanks to the publishers of these journals and also to the writers of the articles collectively, for the valuable data and information which have made this compilation possible.

It is hoped that the work will assist the present-day mechanic in the design, construction, and use of expedient and economical gages and gaging systems, and that it will also be the means of increasing the output and efficiency of duplicate machinery, and at the same time be instrumental in lowering the cost of production on interchangeable work.

JOSEPH V. WOODWORTH.

BROOKLYN, N. Y.
January, 1908

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GAGES AND GAGING SYSTEMS

SECTION I

GAGE MAKING; FUNDAMENTALS, PRACTICE, DEVELOPMENT AND EFFICIENCY OF THE TOOLS.

GAGES AND GAGING SYSTEMS — THEIR USE

WONDERFUL indeed has been the progress made during the past fifteen years in the production of interchangeable machine parts, and repetition articles of cast, machined, punched and stamped metals. Now it goes without saying that this progress is due more to, and has been directly brought about through, the introduction of gages and gaging systems for verifying measurements and insuring the production of none but perfectly interchangeable parts; or at least for the guaranteeing of the parts coming within an allowable limit of variation.

In the development of gages and gaging systems we may trace a line of mechanical development, efficiency in the operation of machinery and tools, and the elimination of hand labor that is simply phenomenal. It may therefore be stated without fear of contradiction that the perfection of the modern interchangeable manufacturing system, the cheap and rapid producing of accurate jigs, tools, dies, and fixtures for machining and producing repetition parts, could never have been attained but for the development and introduction of the numberless varieties of testing and gaging instruments which have to-day been adopted in the most progressive shops where accurate duplicate work is produced.

In this and the sections which follow, it is our object to illustrate and describe the design, construction, use and application of gages and measuring instruments, which may be adopted to advantage in numberless machine shops and manufacturing establishments throughout the world, to there supersede hand labor in the production of metal parts and to also insure the verification of their interchangeability.

While the use of gages has progressed wonderfully in the larger manufacturing establishments and is becoming more generally understood and appreciated every day in the smaller ones, there are nevertheless many others wherein their proper design and construction, together with their value and application, are not understood. In such shops where these error detectors are not used, tools, parts of machines and small articles of metal are being laboriously brought down to interchangeability by hand work, and then tested for accuracy by tedious and unreliable methods; and the same labor could be accomplished in one fourth the time by means of suitable gages of inexpensive construction placed in the hands of workmen, who should be taught how to use them properly.

Aside from the reduced cost of producing machine parts and articles of metal, which invariably results through the introduction of a proper gaging system, the increased efficiency of the articles produced is a factor that has to be considered.

Manufacturers, managers and superintendents of machine building and metal working plants should realize once and for all, that unless they install an up-to-date gaging system and place properly constructed gages in the hands of their operators, the production of parts that *will* interchange at any and all times and places is impossible.

SHOPS IN WHICH GAGING SYSTEMS ARE UNKNOWN

We have inspected a great number of establishments all over the United States, and we have been employed in them also; from the small back-loft jobbing shop to the great machine works; and we have come across a wonderfully large number wherein the proper use of gages and gaging systems was unknown and unheard of. Therefore, we state that if any superintendent of a shop wherein the use of modern gages has been ignored will make a trip of inspection through the departments of the works which he directs, he will not have proceeded far before becoming possessed of a painful realization that his concern is paying for a lot of unproductive labor. If he is at all progressive he will then give up some of his time to the study of gaging systems, to a gaining of a proper knowledge of the use of gages, and, afterwards, to the introduction of a proper system of gaging in his departments. More and

better work will be the result of this innovation, because interchangeability and efficiency of the articles and parts will be guaranteed before they leave the hands of the machine operators. There will then be no chance for inaccurate work leaving the shop; there will then be no opportunity for the assembling of inaccurate parts into machines or tools. Lastly, economy will result through the cutting out of operations formerly requiring skilled help to perform, and through the elimination of much hand labor. The operator's skill will become an ineffective factor, except with regard to the quantity of the output, because the use of gaging tools will insure the production of perfect parts.

INTERCHANGEABILITY AND MEASUREMENT INSTRUMENTS

From a mechanical point of view it may well be said that we are living in an age of interchangeability brought about through the use of and perfection of instruments for measurement and detection of error. Never before have mechanics and manufacturers, and in general has the world of industry, made use of gages and gaging systems as it is doing now. And there is small wonder for this state of affairs, for these useful tools in all their different phases have proven to the satisfaction of the greatest mechanical economists of to-day that they are instruments that work for the reduction of cost of production, the perfect efficiency of products, and the education of, and increasing the skill of, the productive workers.

Of course, to those who are unfamiliar with the gage and its modern application, the statements contained in the foregoing may appear extravagant; but one has only to inspect a modernly equipped and perfectly operated manufacturing plant wherein accurate machinery is built in large quantities, to become convinced of the surprising rapidity with which the machine tools in use therein turn out accurate work in a steady stream, — with the operators simply occasionally testing a piece with their measuring instruments, — through the use of gages and the proper installation of gaging systems.

Of the many different kinds of gages, the ancient snap and plug gages are the most widely known and used. The reason for this, we might say, universal use of these two types is, that almost

all work that requires the use of various other kinds of measuring instruments requires the use of one of these two first.

GAGE MAKING

In gage making, as in the construction of all verifying instruments, the fundamental quality that works for success, and upon which all subsequent results depend, is accuracy. This the mechanic must always keep in mind from the very moment he cuts off the stock until he has concluded the finish lapping. If any error does creep in during the construction of a gage it will, in all probability, mean a great deal of spoiled work if it is allowed to get by unheeded, and all subsequent care in performing the remaining operations toward completion of the tool will not avail in eradicating the error. Of course, if the error is such that upon investigation it is ascertained that it will not affect seriously the interchangeability or limit of variation allowable in the parts upon which the gage is to be used for measurement verifying, then the case is different, as the defect will have no effect in preventing the attainment of what the tool is required to indicate.

MAKING A TAPER PLUG AND RING GAGE

In order to lay before the reader the methods of gage making, it will be well to take up and explain in detail first the making of a small taper plug and ring gage, as in the construction of tools of this type, accuracy, skill, patience, and workmanship of the highest order are absolutely necessary.

Of the steel question we will simply state that no grade of steel, however good, is *too* good for gage work; therefore secure the very best grade of steel in the market. The expenditure of a few cents per pound over the usual price should not deter one from procuring the very best, when it is considered that the cost of material however great is not to be compared with the cost of labor that will be necessary to finish the tool. Besides, a very small defect in the raw material will often not make itself evident until much expensive work has been done; then, as the tool is of no use, the loss is great. A steel that can be depended upon in annealing, hardening and tempering; a steel that will not shrink or warp excessively; a steel that when hardened will have the minimum of spring in it; that is the steel to use for gage work.

The fact is well known that it is extremely difficult to produce a perfect taper plug and ring gage of special size. Of course, in standard sizes of these gages, they may be had of manufacturers with their accuracy and efficiency guaranteed, because these people make a specialty of manufacturing lines of such tools, and their workshops are fully and splendidly equipped for turning out such tools in quantities.

In the making of a special size of taper plug and ring gage, it is quite impossible to secure a perfect fit by simply lapping the tool in the ordinary manner after hardening. This is so because the diameter is so small that it is usually quite impossible to use a wheel to grind it; therefore it becomes necessary to use the diamond charged lap to finish it. This lap is not used in the same manner that the ordinary lap is worked: instead, it is used in a manner similar to the use of a wheel for internal grinding, the diamond-charged lap being placed in a traverse grinder or a bench lathe, and with the female gage held in the chuck of the lathe, it may be ground easily and accurately, care being taken not to crowd the cutting qualities of the lap. The result of forcing the cutting of a diamond-charged lap of this kind is a finished gage that is "bell-mouthed."

When using the diamond-charged lap for work of the kind above indicated, it will always be found best to keep the lap well lubricated with kerosene oil. Lubricated in this manner the lap will be found to cut much more freely than if used dry. The results will also be much more satisfactory.

The diamond powder used in charging laps for grinding gages may be had in different grades, each grade being known by a number. On fine grinding, No. 5 will be the best to use. On ring gage work, however, the grade known as "ungraded" answers all purposes in a most satisfactory manner.

GRINDING OUT SMALL RING GAGES

When grinding out very small ring gages, necessitating the use of extremely small laps, it is quite difficult to ascertain if the lap is doing any cutting as the work revolves. In order not to take advantage of this to crowd the lap unknowingly, a little tool known as a "transmitter" comes in handy. This "transmitter" can be quickly and easily made of a piece of, say, No. 29

drill rod, one end being split for about half an inch up, and its two parts spread so that they will straddle the spindle of the traverse grinder. On the other end of the rod fasten a piece of wood shaped in a neat and comfortable manner so that it will rest against the ear of the workman. This arrangement will act as a telephone, and indicate to the operator when the lap is removing material inside the gage.

After a taper ring gage has been made, it will be well to make a perfect lap of the right taper and lap just sufficient to remove the marks left by grinding, which are usually very slight.

GRINDING AND LAPPING A MALE PLUG GAGE

The male or plug taper gage is more easily made and finished than the female. It can be more easily handled and can be readily ground in a universal grinder. It can then be lapped with a piece of babbitt that has been finished off perfectly straight, and the finished surface charged with emery.

In the making of sets of these gages the plug gage is usually made first. This is done so as to be able to use it as a reference gage when grinding out the female gage. However, when the mechanic is supplied with a model to which to make the tools, then the female gage is made first and the plug afterwards fitted to it.

PREPARATION OF EMERY FOR LAPPING GAGES

An essential necessary to the workman who desires to become a first-class gage-maker is a thorough knowledge of the proper preparation of the emery for lapping. It should be prepared in the following manner:

Take a quantity of flour emery — say about five tablespoonfuls — and mix it with a cup of good lard oil. Thoroughly mix the two materials together and allow the mixture to stand over night. In the morning pour the mixture off into another cup, and take extreme care not to disturb the settlings, as these settlings are composed of large grains of emery and should be thrown away. Repeat this pouring operation three or four times, and the result will be a mixture that will produce an elegant finish on the surfaces of both male and female gages.

LATHE ATTACHMENT FOR FACILITATING THE CUTTING OF THREAD GAGES

When the last cuts are taken on the thread, it must be within one ten-thousandth of an inch. For this reason a large disk, shown at *a*, Fig. 1, is of service. It should be as large as the lathe will permit; in this case it is $4\frac{1}{2}$ inches in diameter and $\frac{1}{2}$ inch wide on the face. It is turned out $\frac{3}{16}$ inch from each side to make it light and neat in appearance. The disk is fastened to the cross-feed screw with a knurled screw, and is graduated in

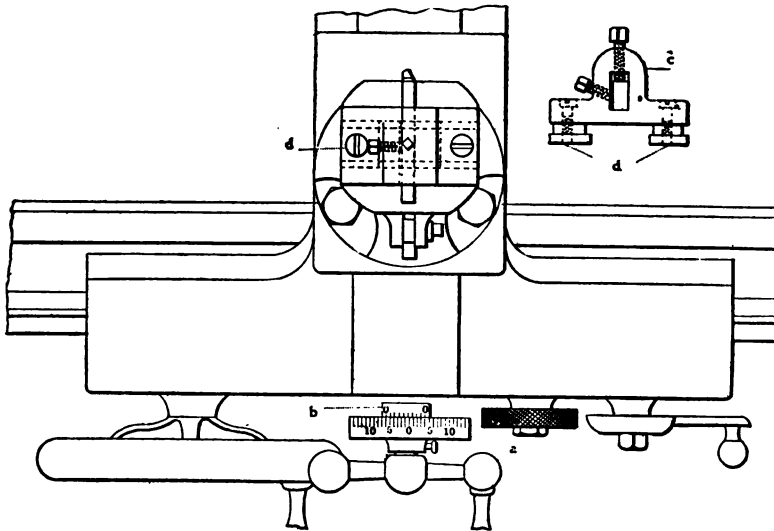


FIG. 1.— Thread Cutting Attachment.

250 divisions, and stamped on each side of the zero line from 0 to 125. Arm *b* is made the same radius as the top of the disk, and fits the hub of the cross-feed bearing. It is split at the end and clamped stationary with a machine screw. The graduations on top are ten in number, and occupy the same space as nine divisions on the disk, and for convenience in reading are stamped 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0. Accordingly, when a line on the disk coincides with the first line of the vernier, the next two lines to the right differ from each other one tenth of the length of a division on the disk, the next lines differ by two tenths, etc. This design gives the thread chaser a positive position when feeding

in for a finishing cut, while with the ordinary micrometer dial to feed in less than one thousandth of an inch is a case of guess work, and the consequences very likely are that the tool feeds in too far, the chaser begins to tear, and the thread gets rough and loses the correct shape and lead. The chaser should be filed on both sides the same angle as the thread, so it will start and end with a full thread, and not more than three threads should remain on the chaser; then it should be hardened in an open fire and drawn to a light straw.

Another good attachment for thread gage cutting is the stationary tool-post *c*, Fig. 1, which takes the ordinary style of chaser. The post is fitted rather freely to the T-slot in the tool-block and clamped with two machine screws and two nuts *d*. A set-screw at the top and another at the side clamp the chaser, and after the tool-post has been once located and set square, the chaser will always be located properly after grinding. Where a tool-holder is used with a removable threading tool, this tool-post is not required, as the chaser point will drop squarely into its seat after grinding.

MEASURING GAGES WHEN THREADING

A good method for measuring the thread when finished is to measure in the thread angle by using an ordinary micrometer and wires of different diameters. To measure large threads, procure an ordinary micrometer head from any of the manufacturers of measuring instruments, making a C-shaped frame like an ordinary micrometer body, except that the anvil should be $1\frac{1}{2}$ inches in diameter, and the frame flat on the bottom so it will stand upright; bore a hole in the top of the frame to fit the micrometer head, and at the same setting turn off the face of the anvil. Great care should be taken, after hardening the anvil in grinding and lapping, that it is perfectly square with the micrometer stem.

POINTS IN GAGE SETTING

When cutting a screw plug gage it should be roughed out with a single-thread tool, within .002 inch, and then merely finished with a chaser so as to prolong the life of the chaser. It has been found when chasing that the lead of the lathe is not in all cases

exactly the same with each cut. To make sure that the lead is perfect when the last cut is taken, go over the work three times with the chaser in exactly the same position, and by using a magnifying glass see whether the tool cuts any at either side of the thread; if not, then the lead is all right. The chaser should never be fed in more than .0003 inch with the first cuts, and .0001 inch with the last two cuts, to assure a smooth thread, and it is advisable when cutting to keep the screw well lubricated with lard oil, and for this purpose a square tin box and finger brush for the oil may be kept under the chaser.

A ring thread gage is made in a similar manner, but it is never finished with an inside chaser, except where such is required, where taps are not at hand. After being roughed out with the chaser it is finished with two or three taps with a difference of two thousandths in diameter. On smaller ring gages inside chasers cannot be used, but a set of taps, six in number, are used, these varying in diameter, one from another, by from two to five thousandths of an inch.

RENEWAL OF THREAD GAGES

An item which we think will be of interest is the renewal of thread gages, with which no doubt we have all had the same difficulty. Three plug and ring gages are made at the start, all on the same lathe, and hence all alike. The trouble begins when the foreman brings the manufacturing or the inspector's gage with instructions to renew the plug, as the old one is worn below the standard size. The old plugs were made some time ago. Perhaps you were not around when they were made and do not know what lathe was used, or the plugs may have been made by an outside firm. As the pitches of lead screws on different lathes are seldom alike, it is necessary to find a lathe to cut the thread nearest to the master plug. Should a lathe be used that has an error in its screw of a couple of thousandths in the length of the thread on your master plug, trouble will follow. Making the new plug with .002 for lapping, then hardening it and lapping it to accurate size, it will start in the master ring gage a perfect fit, but on screwing it in a few threads it becomes tighter, and by the time it is half to three quarters through the ring gage, it fetches up solid. You take it out and caliper it, thinking you may have

lapped it a little taper, but finding the plug perfectly parallel, you may suspect that the master ring is a little bell-mouthed on one side and try the plug in the opposite side of the ring gage, only to find it acts in the same way. What is the trouble? Nothing but a slight error between the two leads. Should an attempt be made to lap it enough to bring the lead on the plug the same as on the master, the result would be a very poor fit when only a few threads are entered in the ring gage.

INDICATOR FOR THREAD GAGES

We find we cannot make a good job of a plug and ring if the variation in the two leads is more than .0003 in the length of the

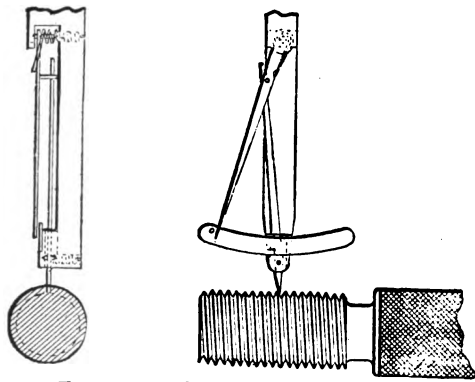


FIG. 2. — Indicator for Thread Gages.

thread on the plugs. To overcome this difficulty, we made a little tool, or indicator, shown in Fig. 2, for comparing the lead of any lathe screw with that of the master thread plug. Putting a dog on the master plug, placing it in the lathe and holding the indicator in the tool-post, with the lathe geared to the proper pitch, we place the indicator against the side of the thread on the master plug hard enough to bring the pointer to the zero mark, and then start the lathe very slowly in order to watch the pointer. If it remains throughout the whole length of the master plug at zero, one may be sure that he will be able to make a plug on that lathe that will not fetch up tight when half way through the ring gage.

The proportions of this indicator are such that it multiplies 100 to 1; thus, .001 of an inch in a thread will show .100 of an

inch on the graduated plate. A zero mark is placed at each end of the plate, the graduations reading each way and marked 1, 2, 3, etc., thus reading, .001, .002, etc. The levers swing on pivots with 60-degree points, which are adjusted by fine small, fine-thread screws, acting as the lower bearings of the pivoted levers. A small coil spring encircles the rear pivot, and bears against the last lever to maintain proper pressure. When the indicator is brought against the thread, it wants to bear hard enough to make the last lever stand at zero.

This indicator is also a very useful tool for finding if a lathe will cut a micrometer screw. Take the screw out of a micrometer which is known to be right, and remove the barrel from the screw. Chuck a piece of steel or brass in the lathe to be tested, and bore the end to fit the measuring end of the micrometer screw with the thread projecting. Gear the lathe to 40 pitch and apply the indicator, and you will soon know if a micrometer screw can be cut on that lathe.

It is often good policy when making thread plugs and rings, to rough them out without cutting the threads, and harden them as if they were finished, and then anneal and cut the threads. This process no doubt does away with a lot of expansion and contraction of the steel in the second hardening. Some like this method, others do not. We have had very good success with it.

A THREAD-TESTING GAGE

A very efficient thread-testing gage has recently been patented by the Dresdner Bohrmaschinen fabrik A. G., formerly Bernhard Fischer & Winsch, of Dresden, Germany. The handling of this new device, as shown in Fig. 3, is simple and easily learned. Screws can be tested by it not only to any degree of accuracy, but the external diameter, diameter at a root of thread, pitch, and form of thread may also be ascertained.

The testing gage, Fig. 4, comprises two hardened and ground members parallel to one another, solidly connected by cross-pieces having large contact surfaces and screws. In one of the members *A*, the shape and depth of the thread has been accurately worked, while the adjoining surface *B* corresponds to the external diameter. On the opposite ends of the gage, both legs are smooth, spaced apart the minimum width admissible for the external

diameter of the screw. These sizes are indicated on the gage for each size.

The gage is used as follows: One first tries to introduce the screw between the two smooth terminal surfaces *C* of the legs; if it enters the external diameter is too small, so that the screw being unavailable need not further be tested. If, however, the screw does not enter, the test is continued on the opposite end. The screw should readily fit into the gage *A*, Fig. 4. On entering the point of the screw, it is ascertained whether the pitch and shape of the thread are correct. If the screw can be introduced at *B* from the side and does not fit in *A* from the front, its external

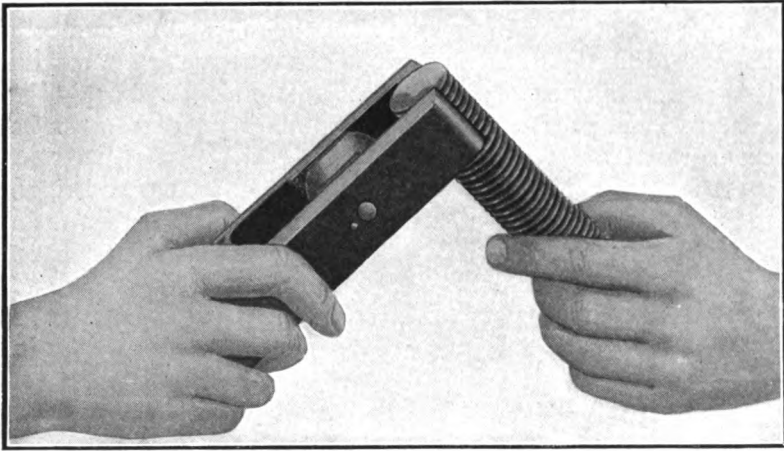


FIG. 3. — Thread-Testing Gage.

diameter is correct, but the pitch is not. Screws having the threads that are not stretched or otherwise deformed do not pass through *A*.

MAKING AND USING GAGES FOR MANUFACTURING MECHANISMS

To-day, when a piece of mechanism or a machine is perfected and ready for manufacturing, the first thing to be considered is the making of the gages, which is oftentimes a very expensive item, especially when the mechanism is of an intricate nature. To obviate errors in the gage making is a very essential point in this class of work, as an error in one gage may affect the accuracy of others, or, in other words, this inaccurate gage may be used as a

master to make others too, they in their turn being used on different parts of the mechanism. Thus the error may be multiplied a number of times before being detected, and when at last found it is oftentimes a difficult matter to correct it, as it may be that that same error has by that time established a size of its own to which many other gages have been made, and to rectify it may mean the overthrowing of all the gages that have followed the making of the first incorrect one. So it is obvious that the greatest foresight and skill must be exercised when making the masters. It happens many times that a man is given a gage to make, with orders to get it as nearly correct as he possibly can. The tool

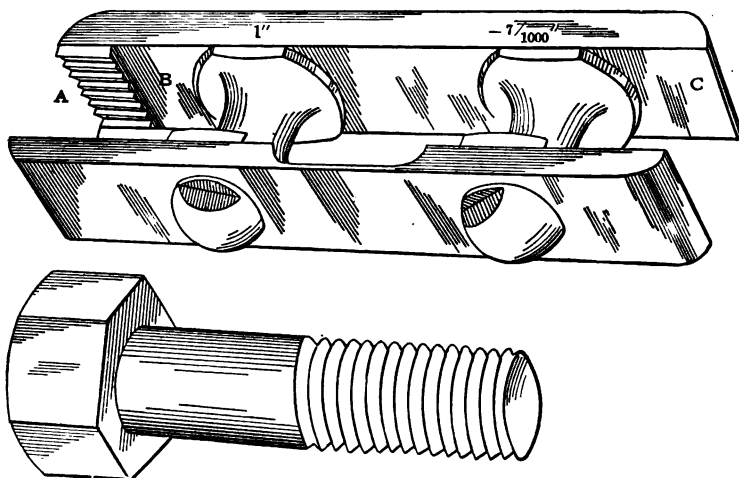


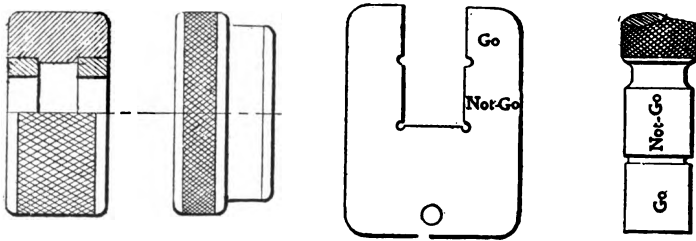
FIG. 4. — Thread-Testing Gage.

may be nothing more than a distance gage for locating one hole from another, and, moreover, it may be that the second hole is only a screw or clearance hole. The tool-maker criticises the foreman's orders for requiring unnecessary exactness, but the foreman knows why he gave those orders. He sees, perhaps, that he must use that second hole as a gaging point to locate another or third point from, as the gaging of this from the first hole would require an unpractical gage; or there may be some obstruction in the way so that he cannot avoid measuring from the second hole. We do not advocate, nor is it advisable to use more than one point on a job to gage from, but oftentimes it cannot be avoided.



RING GAGES

We wish to mention right here a point which has often been brought to our notice, and which, while having nothing to do with the accuracy, does concern the construction of all classes of limit gages. Take, for instance, the ring gage shown in Figs. 5 and 6, having two hardened and lapped bushings, one in each end of the large knurled ring which acts as a holder; there is a difference of .001 inch in the inside diameter of these rings, or .0005 inch limit each way from standard size. The knurled ring is marked with the respective sizes, and on the ends are stamped "Go" and "Not go." Now these little words tell at a glance which way the gage is to be turned, but we think the words are not sufficient.



FIGS. 5, 6, 7, and 8. — Limit Gages.

A man working on a machine picks up that gage and uses it, perhaps, many hundred times a day, and without taking the trouble to look at the lettering he will try it on the work, turning it end for end, may be, to find that neither end will go on the work. Now if that same gage was made, as in Fig. 7, so that the large end marked "Go" was distinguishable in form from the small end, the man manipulating the gage would, when picking it up, naturally turn it so that the big end could be tried first; if that would not go on he would know it would be useless to try the other side. We have been requested by several men to chamfer one of the edges of such ring gages for just that reason. There are some limit gages made as shown in Fig. 8, and on such it is not necessary to follow the above practice as their position need not be changed to discern the respective sizes.

COMBINATION BENCH GAGE

Fig. 9 shows a small combination bench gage used for testing the diameter of a ball, also at the same setting showing if the hole is concentric with its outer diameter; this last named operation is accomplished by a lever, the end nearest the fulcrum

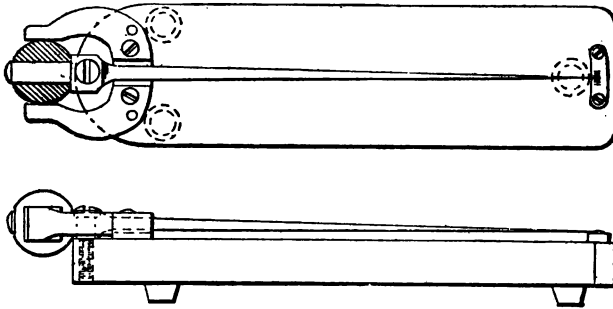


FIG. 9. — Combination Bench Gage.

being hardened, ground and lapped to fit the hole in the ball, while the other end multiplies any eccentricity of the hole, the ball itself being held central by a snap gage fastened on the main plate.

DIFFERENT FORMS OF PIN GAGES

Pin gages are made in many different forms and, are often used as limit gages. They are employed mainly in gaging sur-

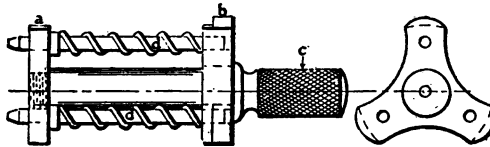


FIG. 10. — Pin Gage.

faces that are obscure — say at or near the bottom of a hole. Fig. 10 shows such a gage constructed for determining the depth of a hole. It is composed of two plates, *a* and *b*, which are cut away so that they will have a three-point bearing in the hole; both are hardened and ground, and plate *a* has a tapped hole through its center, a hole in which the handle is a press fit, this handle holding both plates in alignment. The three pins *d* are hardened and lapped at both ends, and there is a small collar on

each against which the spring acts, giving them a downward pressure. The plate *b* has its outer diameter turned and ground so that it fits about one third of its width into its hole, while the remaining part rests on top of the work. The top face of *b* is lapped to a level surface. When the gage is placed in the hole to be tested, the lower ends of the pins come in contact with the bottom of the hole, and by a little pressure on the handle the upper plate is then forced down to its seat on the work, the pins projecting through the holes in this plate, unless the hole is of proper depth, when the tops of the pins must be perfectly level with the top face of *b*.

Fig. 11 shows another style of pin gage, this one being constructed for gaging the recess shown in the accompanying piece of work. It is composed of the body *e*, which is hardened, ground and lapped on its two flanges, and has a straight hole through

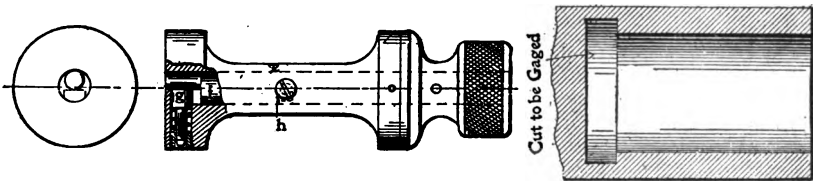


FIG. 11. — Pin Gage.

its center, also lapped out, to receive the hardened and ground plug *f*, which in turn has an eccentric ground on one of its ends, this operating the gaging pin *g* which is held against the eccentric by a small spring. The small screw *h* engages in a slot milled into *f*, and allows the latter to make a half turn. Secured on the end of *f* is a knurled head, one end of which is turned to form a flange whose diameter coincides with the end of *e*; on these two flanges are zero, or limit lines, as the case may be. The location of these lines is governed by the length of pin *g*, the depth of the cut to be gaged, and the throw of the eccentric.

Fig. 12 shows a very simple gage which has several advantages, one of these being that the original size of the gage can never be lost. The two collars *ii* are hardened, ground and lapped to the required thickness, thus the size of the gage is established and can be maintained with very little trouble. On these two collars are held two plates of hardened steel, one side of each being ground and lapped and this side resting on the collars. To com-

pensate for wear the hardened plates are removed and relapped, so that they will be perfectly straight, and are then replaced without in any way affecting the gage size.

Lastly we endeavor to show a gage that is extensively used for testing the size and parallelism of a hole, and mainly adapted

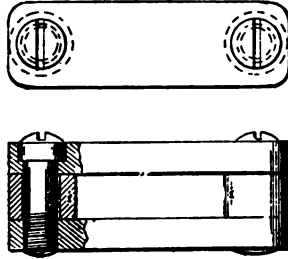


FIG. 12. — Simple Test Gage.

for holes that are at least 3 inches in diameter and of unusual length. Its construction is as follows:

Part *j*, Fig. 13, is a head into which screw the three sleeves *k* and the tube *l*. The latter is a piece of seamless steel tubing carefully straightened, and with one end bored out to receive the hardened and lapped bushing *m*, and the other end bored to

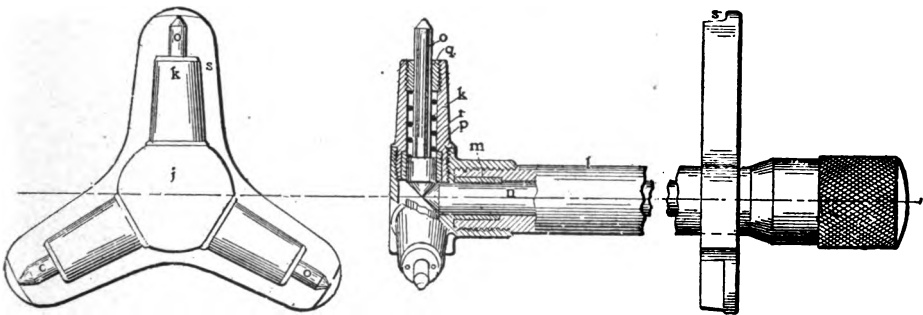


FIG. 13. — Three-Point Test Gage.

receive the micrometer nut. On this end are located also graduations similar to those on a micrometer. One end of rod *n* acts as the micrometer screw, while the other end is hardened and ground and lapped to a running fit in bushing *m*; this same end is ground and lapped off to a perfect 45-degree cone, which acts on similar ends on part *o*, serving as the measuring rods, these

being hardened, ground and lapped and the largest diameter fitting in the hardened and lapped bushing *p*, while the smaller part slides through the nut *q*. The spring *r* tends always to hold rods *o* against *n*, and part *s* serves to hold the micrometer end of the gage in alignment, it being a sliding fit on tube *l*.

VARIATION IN SIZE OF WORK DUE TO TYPE OF GAGE

The following is a summary of some experiments made in connection with a limit gage system shown in Fig. 14, which we

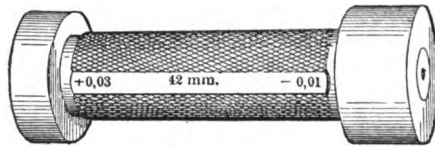


FIG. 15. — Plug Gage.

were called upon to lay out for a large Austrian iron works. The gages were to range from 6 millimeters ($\frac{1}{4}$ inch) up to 250 millimeters (10 inches); but we decided to replace the heavy and extensive plug gages, Fig. 15, with the cheaper flat bar gage,

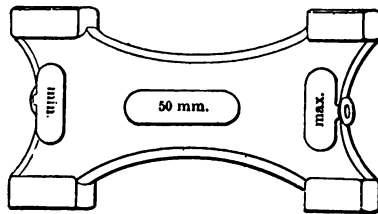


FIG. 16. — Flat Gage.

Fig. 16, in sizes from $2\frac{1}{2}$ to 6 inches, and with the spherical end rod gages, Fig. 17, in sizes from 6 to 10 inches.

Having grown cautious by experience in the shop, we made trials of $2\frac{1}{2}$ -inch holes with all three kinds of gages after the following plan:

Three holes of nominally the same size — $2\frac{1}{2}$ inches — were commercially made: Hole 1 to a plug gage, Fig. 15; Hole 2 to a flat gage, Fig. 16; Hole 3 to a rod gage, Fig. 17. Hole 1 was so made that the go-in end of the plug gage passed with a good sliding fit, feeling friction all over. It is generally assumed in such cases that the hole must be at least 0.005 millimeter (about

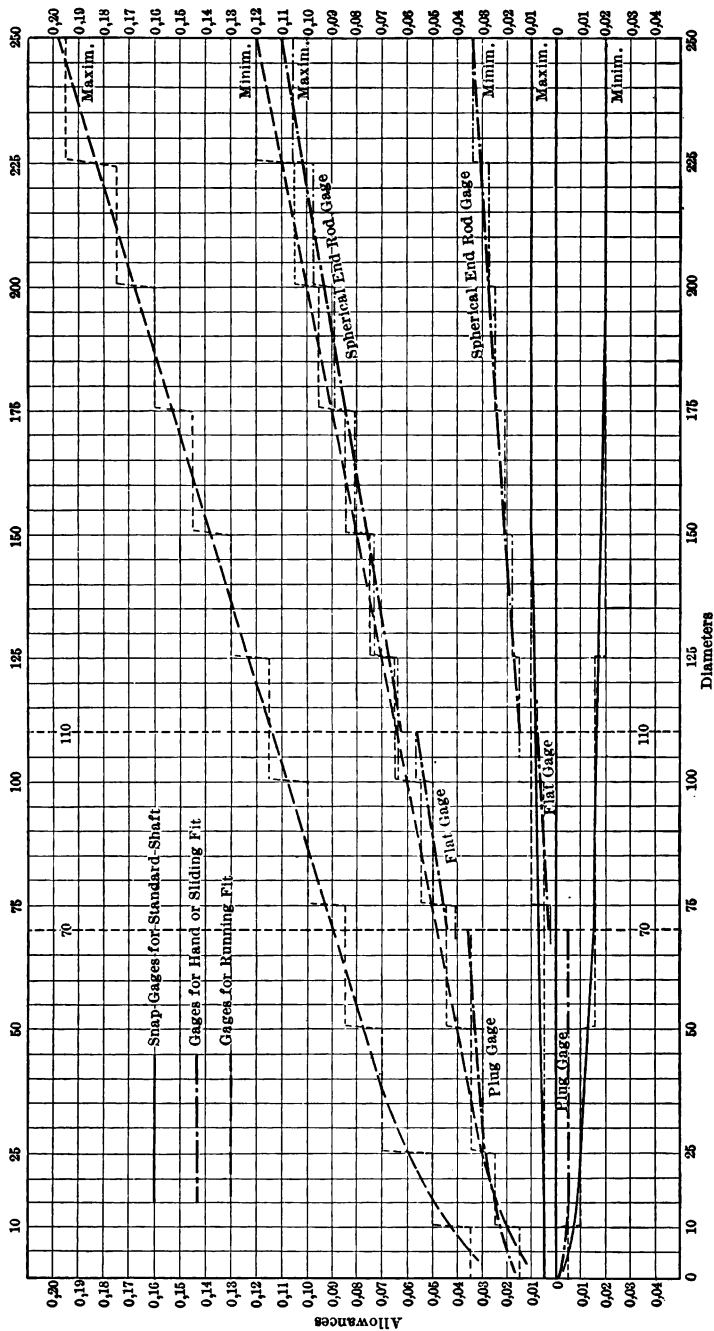


Fig. 14. — Limit Gage System.

0.0002 inch) larger than the gage. When the same hole 1 was tested by the flat gage, the go-in end of this gage fell easily through it, and the rod gage passed still more easily, whereas the small end of the flat gage goes into hole 3, an absolute proof that the difference between a plug gage and its hole must be greater than is generally supposed. To be sure, larger new gages, Figs. 16, 17, were made, till we felt the same friction by putting them by hand through hole 2, and found that they ought to be made 0.012 millimeter in the case of Fig. 16, and 0.02 millimeter in the case of Fig. 17, larger than the corresponding plug gage.

The gage system shown in Fig. 14 was consequently laid out with the flat and rod gage dimensions increased in reference to the plug gage measurements, as illustrated by the broken line. The starting point for the system in question was the standard shaft; it was decided to provide hole gages only for running fits and for push fits, or those that could be entered by hand or by a



Spherical End

FIG. 17

wooden block, that is, a good sliding fit. There was a very little need for keying and force fits.

At the same time we found by sharp inspection by the flat and rod gages, that almost all holes were oblong, *i.e.*, they had different diameters in different panels. This cannot be discovered by a plug gage, but a plausible reason is the fact that the plug gage did not enter where the others did. The whole thing is not at all astonishing, because everybody knows that the finest touch (and at the same time the most difficult measurement) is made: (I) by a rod gage with the rounded points, point touch; (II) by spherical end rods, Fig. 17, supposed line touch; (III) by flat gages, Fig 16, supposed small surface touch; (IV) by plug gages, Fig. 15, supposed cylinder surface touch.

We say "supposed" because by consideration the touch of each group, IV, III, II, I, must go back respectively to III, II, I, 0; for it is obvious that each gage must be at any rate smaller than the hole to be tested, and consequently the two circles of hole and gage are eccentric, and reduce the touch surface to lines,

and so forth. And this must be true even for the Whitworth plug and ring. We all know by experience how difficult it is to insert a plug into a ring of the same size, say $2\frac{1}{2}$ inches. It is necessary to grease both with the best vaseline, and if we succeed in entering the plug without using the general tool-maker's trick of talking to the observer while warming the ring in the meantime by the hand, we always see afterwards the interference colors in the grease, an evident proof that there was no metallic, but a grease touch between plug and ring, which means that the ring was larger than the plug. No one risks putting them together dry; there is no doubt the surfaces would seize one another at once.

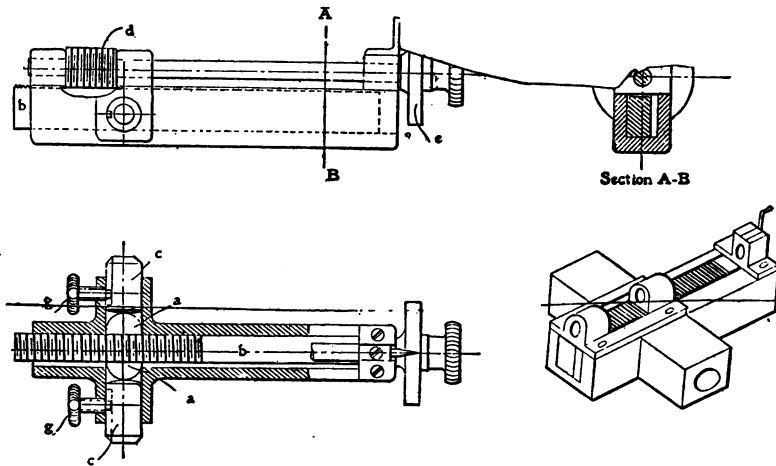


FIG. 18. — Gage for Internal Hole Measurement.

Finally, we inspected the standard ring by the end rod, which was exactly $2\frac{1}{2}$ inches in diameter, and found a much easier fit than with the standard (greased) plug. We concluded, consequently, that in general manufacturing the irregularities of holes are so great that in reality for $2\frac{1}{2}$ inches in diameter we get holes of about 0.02 millimeter (0.007 inch) larger than we supposed. This additional factor is smaller for small and greater for great diameters.

Because we started with the Whitworth plug and ring, we tried to design an instrument for internal hole measurements, which is illustrated in Fig. 18. The tool is manufactured by the Loewe Co., Berlin. The flattened balls *a* which serve to bring

the pressure of the wedge *b* without pinching to the small rods *c* which are very carefully fitted to their rods without play, are only intermediate pieces to secure a correct connection of the different parts. The two thumb-screws serve to fix the end pieces for testing snap gages, explained later on. The inclination of the wedge is 1 to 100, the pitch of the screw *d* is 1 millimeter, and the micrometer head has 100 divisions; thus we can read 0.0001 millimeter change in the distance of the two measuring ends. The original distance is adjusted by a measuring machine, and then the instrument is put into the hole and readjusted, until the inspector feels the touch. At the end the increase is read on the scale and supervised by the measuring machine. These trials confirmed the first conclusions. For measuring holes the pieces *c* have spherical ends instead of flat ones. The diameter of the sphere to which the ends are ground corresponds to the smallest hole to be measured. Because the holes are always larger than this the inside walls of the hole are always touched by the center and never by the corners of the pieces *c*. The spherical rounding with great diameter has been done for convenience to superinspection on the measuring machine. With flat end rods inserted, the instrument is very useful to replace in the tool-room very expensive sets of end pieces or combination rods for testing snap gages of limit systems having different allowances but the same nominal size. Of course, the measuring machine is an indispensable complement to this sort of gage.

SOME GAGING AND MEASURING METHODS AT THE WORKS OF THE WESTINGHOUSE MACHINE COMPANY

The basis of all shop gaging done at these works is an 8-foot Pratt & Whitney measuring machine, with which standard exact inch rod gages have been made as required until the works have a complete set of whole inch lengths up to 80 inches. These rods are used for adjusting caliper gages, shown in Fig. 19, all of which, except the micrometer heads, are home made. In making these calipers a good deal of care is given to obtaining exact alignment of the micrometer head and the anvil screw, but otherwise they are of every-day workmanship. The anvil screw has considerable range of adjustment, and the calipers shown as having an I-beam section of yoke — which form a set by themselves

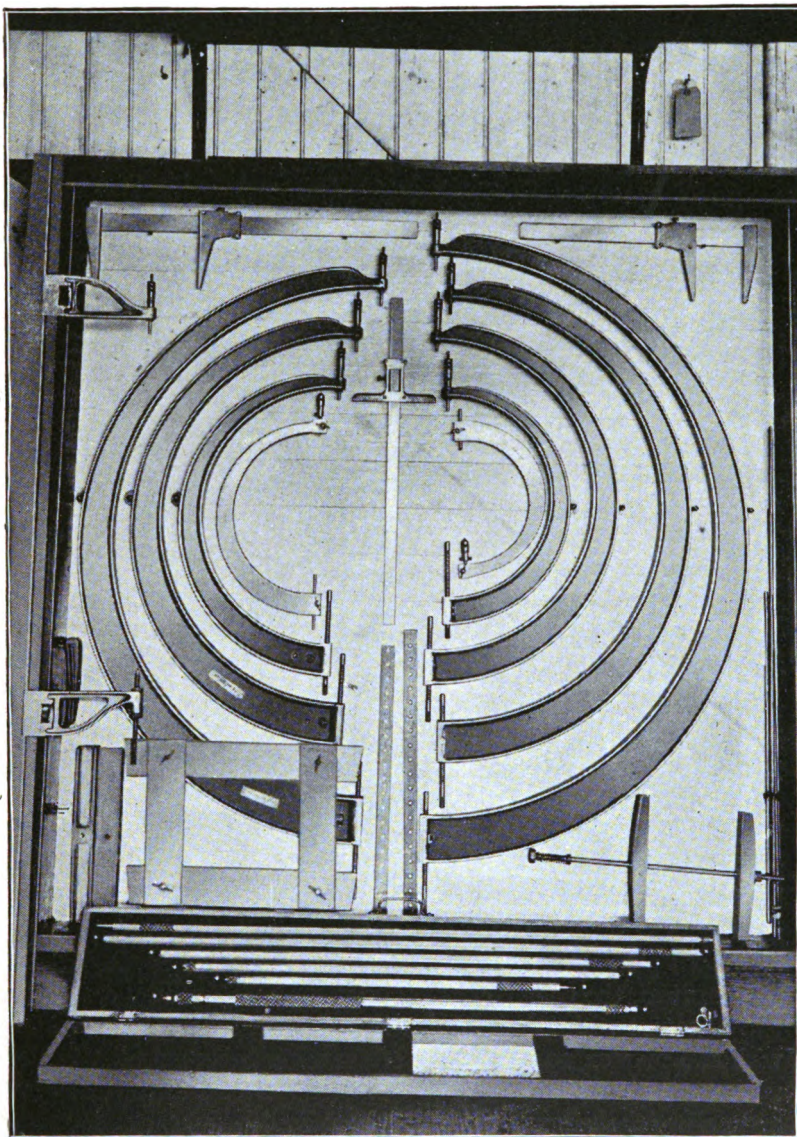


FIG. 19. — Test Rods and Caliper Gages.

—giving thus a range from 10 to 40 inches by the following intervals:

<i>No.</i>	<i>Inches</i>
1,	10-14
2,	14-18
3,	18-22
4,	22-26
5,	26-30
6,	30-35
7,	35-40

The anvil screws have bastard threads, 10 per inch, though Mr. Thomas, to whom these gages are due, thinks that were he to make the set again he would make the pitch 20 per inch instead of 10. As these are used only for adjusting the instruments so that the micrometer heads will read zero for the even inches, they are of ordinary lathe cut accuracy only. The holes in the yoke end for these screws are not threaded, but are bored a neat sliding fit, the nuts being half nuts only and arranged to be clamped to the screws, or quickly disengaged by turning a knurled nut recessed into and projecting through the web of the I-section. This, of course, saves a lot of traversing of the screw when it has to be moved a considerable distance. The yokes are made of zinc-aluminum alloy, and are surprisingly light. The mixture is of 30 parts zinc to 70 aluminum, and the castings were made in the brass foundry of the works without difficulty.

For the delicacy of action a caliper gage must of course be stiff. When made of steel or iron, however, there is increase of weight, and while the stiffness is a necessity, the weight is objectionable because it dulls the sense of touch. The lightness of these instruments is such that the largest size may be handled by one man with perfect ease, and in connection with the appliances to be described, the gaging of the largest shafts is done by one man and of course with far greater satisfaction than would be possible with two men on opposite sides of the shaft being gaged. Those whose experience is limited to caliper gages of steel can hardly appreciate the advantage which decreased weight gives. The calipers are handled with one hand, and the contact of the measuring points with the piece being gaged is felt with the same delicacy and certainty that is customary with smaller work.

The method of using these instruments is unique. An end measure rod surrounded by a wooden case is supported in a vertical position by a stand having a heavy base. Clamped to the upright of the stand is a support for two helical springs which support a stirrup having a hole through its center, through which the anvil screw of the caliper is passed. The springs hold the anvil screw in gentle contact with the lower end of the measure rod, which in this case is 39 inches long, and by adjusting the anvil screw the micrometer head is made quickly to read zero when the micrometer head screw contacts with the upper end of the end measure rod. Should the desired size be a few thousandths above the even inch dimension for a force fit, or a few thousandths below for a running fit, or should it be desired to add any friction of an inch to the length of the end measure rod, the required amount is added by the graduations of the micrometer head when, after clamping the head, the instrument is set for use.

The actual gaging of a 39-inch shaft in the lathe is accomplished in the manner described in the following: Two light sling chains surround the shaft and support a pair of springs similar to those of the end measure rod stand, these springs again supporting a stirrup which holds the anvil screw in contact with the shaft to be measured as the previous one held it against the end measure rod. Held in this way and with the extreme lightness of the yoke, the gaging may be done with the highest degree of satisfaction.

The reader will understand that all uncertainties regarding deflection of the instrument by its own weight are eliminated by its method of support. Its position is the same — vertical — when being adjusted as when being used, and the support is at the same point. Within the set of calipers (Fig. 19) which have been described, two others will be seen which are made of sheet aluminum instead of alloy, and which by reason of their extreme lightness are found to be more sensitive than the others. The one on the left is shown arranged for gaging bored holes, the yoke being very convenient for this class of work, as the instruments may be used with the boring bar still in place.

At the left is a cheap but very effective instrument for use in gaging such pieces as pistons, for which the full depth of yoke is not needed. The beam is of wood, and the sliding heads of zinc-

aluminum alloy as with the full yoke form. In this instance the heads were first made of bronze, but their weight caused them to be discarded without fitting them up.

On the floor below the large case will be seen a set of Starrett inside micrometers, with a full set of extension pieces. These are of course used for gaging holes.

In the lower right-hand corner of the large case is an appliance for gaging T-headed shrink links for securing fly-wheel segments. Fig. 20 shows roughly two segments of such a wheel, the faces *a* being machined. The spring *b* on the bolt *c* clamps the jaws with sufficient firmness to hold them in position, and an inside micrometer *d* quickly gives the distance between the faces, from which the deduction of the specified number of thousandths for the shrinkage allowance gives the length of the link.

Resting on the bottom of the case and to the left of the center is a peculiar gage for the seats of double-beat poppet valves, which should be not only of the correct diameter and taper but also correct with relation to one another. The sharp taper of the gage will be understood from the fact that the bores for which they are intended are for the insertion of additional or "false" seats on which the valves act. The method of using this gage is shown in Figs. 21 and 22. The upper seat is first bored until the upper gage bar — detached from the remainder of the gage — fits it as shown in Fig. 21, the upper edge of the gage bar being flush with the faced seat *a* of the casting. This seat bored, the parts of the gage are assembled, the connecting pins being a snug fit in the holes, and the lower seat is bored until the upper gage bar again fits the upper seat, the lower one fitting its seat also as in Fig. 22, when the relation of the two bores is obviously the same as that of the two gage bars.

Standing vertically on the bottom of the large case and near the center (Fig. 19) are two carefully made strips of steel, each with an upturned end, and with a row of holes down the center spaced one inch apart. These are for use in gaging taper pieces for forced fits, for in the Westinghouse Machine Company's works many forced fits are taper, the taper used being approximately $\frac{1}{16}$ inch per foot measured on the diameter. Fig. 23 shows the method of using these strips in connection with an inside micrometer, the taper being greatly exaggerated. The measurements are not made perpendicular to the axis, but to one side

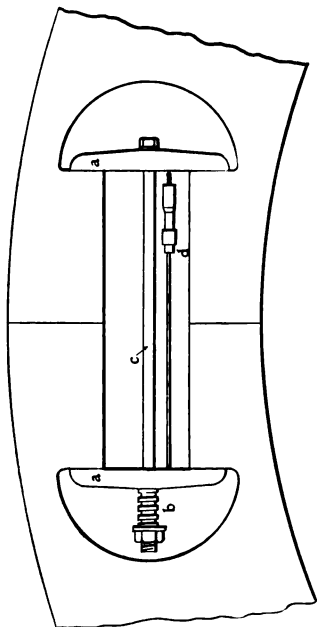


FIG. 20. Gaging a Fly Wheel Joint for the Shrink Link.

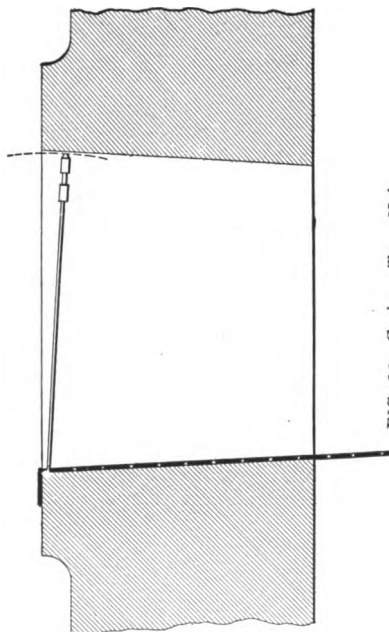


FIG. 23. Gaging a Taper Hole.

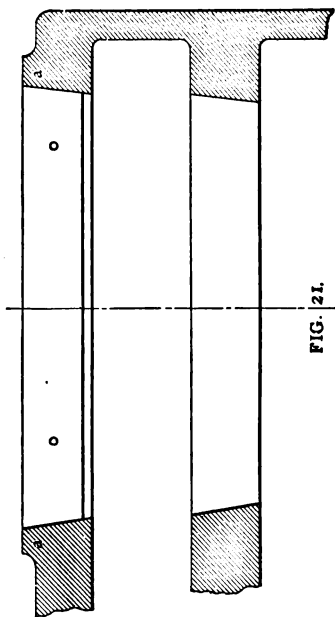


FIG. 21.

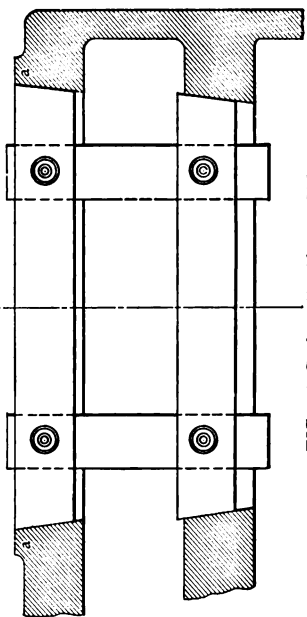


FIG. 22. Gaging a Double Beat Valve Seat.

FIGS. 20, 21, 22 and 23

of the bore. One point of the micrometer being held by a hole in the strip, the other is manipulated precisely as though the bore were straight, as indicated by the dotted arc; and the frequent spacing of the holes in the strip enables the bores to be tested for uniformity of taper throughout its length. The dimension used measured in this way is the one given on the drawing as the true diameter — the microscopic difference between the dimension as called for and as made being obviously of no importance.

Mr. Thomas has much simplified the gaging of these taper holes by a — and otherwise unimportant — change from the former taper of $\frac{1}{16}$ inch per foot leads to decimals for the diameter of one of the ends and for most of the intermediate inches. Thus a hole of 10 inches diameter at the large end, and having a taper of $\frac{1}{16}$ inch per foot, will have the following diameters at successive inches of length when carried out to four places of decimals:

9.9948
9.9896
9.9844
9.9792
9.9740
9.9688

By changing the taper to .005 per inch ($\frac{1}{20}$ inch per foot is equal to .005208 per inch) the values become:

9.995
9.990
9.985
9.980
9.975
9.970

The change in the taper thus gives round figures for each inch of length, and the second set of figures is obviously much more easily read from the micrometer than the first, and, by subtracting from the large diameter half as many hundredths as the piece has inches of length, the small diameter is obtained directly, whereas with a taper of $\frac{1}{16}$ inch per foot, the small diameter can, in most cases, be found only by calculation. One advantage of the taper forced fit is not recognized as often as it

should be. With a parallel fit the holes can be compared only by gaging, whereas with the taper fit the plug may be in its seat and the two compared, the distance remaining for pressing home when the parts come to contact forming the best possible check upon both. Thus with a taper of .005 per inch and an allowance of .01 for pressing the plug should enter the hole within two inches of going home. The adoption of the .005 inch taper simplifies this relation as well as the gaging, as by using this taper, the number of inches by which the parts should not go home when assembled is one inch for each five-thousandths of pressing allowance.

Fig. 24 shows a form of gage for smaller taper holes, such as those for cross-head pins, which Mr. Thomas prefers to a full plug. They are, of course, much lighter than full plugs, and with them

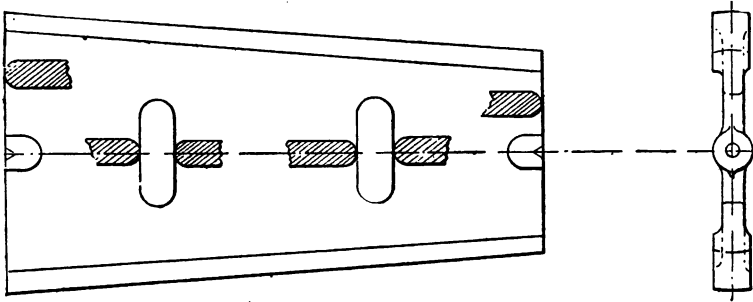


FIG. 24. — Gage for Small Taper Holes.

the holes can be gaged independently on different diameters, while irregularities in the holes are more easily detected.

Fig. 25 shows a very simple method of testing the accuracy of the pitch of taps. The upper view shows that the half nut has but two threads, and by laying the tap in the half nut in two positions, which by the supposed pitch should be an inch apart, and then measuring the distance with the micrometer head, the error may be found and measured.

Mr. Thomas finds, as others have found, that with the best outfit of gages, the old-fashioned calipers still have their place, and Fig. 26 shows such a caliper of large size and made of sheet aluminum. This instrument has a capacity over a full circle of 65 inches and its weight is but $8\frac{1}{2}$ pounds. Mr. Thomas calls it an articulated caliper from the construction of the contact ends. These are jointed to the jaws so as to present faces squarely to

the work, and one of the contact points is adjustable by a fine knurled head screw, this screw being used for the fine adjustment of the instrument.

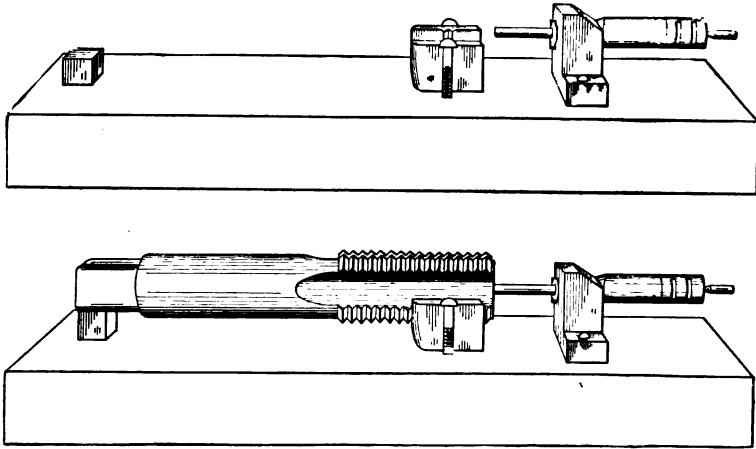


FIG. 25. — Testing Taps.

LIMIT GAGE PRACTICE AT THE WORKS OF LUDW. LOEWE & Co.

We insert the accompanying diagram (Fig. 27) of limit gage practice at the Loewe shops, Berlin, Germany. The illustration

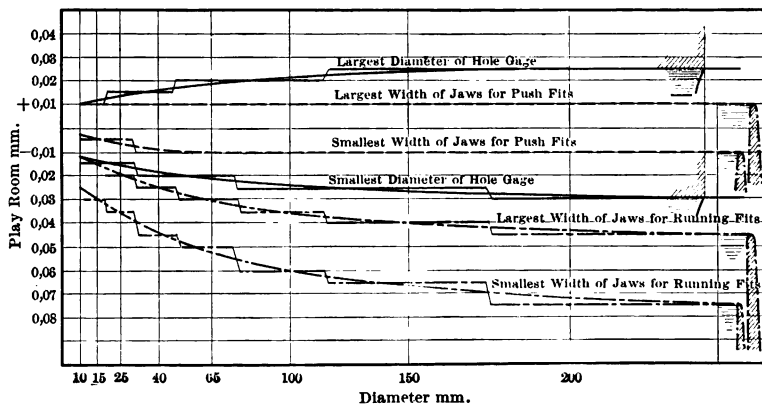


FIG. 27. — Diagram of Limit Gage System.

is a greatly magnified representation of the difference between a series of shafts and holes when adapted to different classes of fits. The abscissas give the nominal diameters. On each side

of the nominal size are descending and ascending lines, which by their distances denote the allowances for running and push fits. This diagram, while printed in the place we find it mainly for

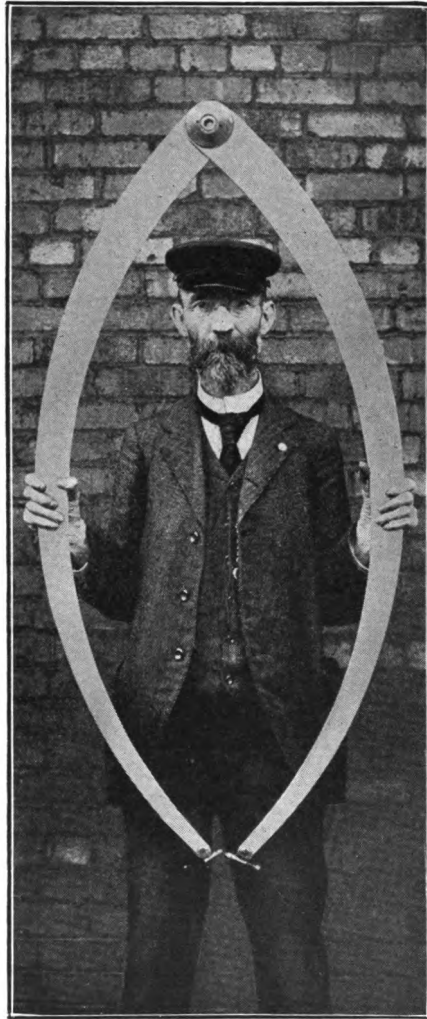


FIG. 26. — Large Size Aluminum Caliper.

illustrative purposes, may reasonably be taken to agree quantitatively with the practice of the Loewe firm, which has established its standards by long experiments and experience.

USE OF GAGES AND INDICATORS IN JIG AND FIXTURE WORK

Without a doubt the "button method" of indicating holes in drill jigs is one of the most accurate that has ever been found, as it has come to be one of the most universal methods in use; but there are many shops in which the use of this system is confined to the use of buttons on work that can be swung in a lathe. When the method has been learned thoroughly, its usefulness will be appreciated for all available work, not only such as can be swung in the lathe, but also on work that is too large for the lathe and which must be done in the milling machine. For this class of work a special indicator is necessary for setting the button in perfect alignment with the milling machine spindle. An example of the usefulness of the button method may be found in a large leaf drill jig for the side frame plates of a cash register, with numerous bushing holes in the leaf, which is too large to swing in the lathe. The location of the holes could, no doubt, be accurately accomplished in several ways, of which the block method is one. By this method a square block, with a hole accurately though its center, is located on the leaf by its outer sides, clamped in position and used as a jig bushing for the drill. We cannot say that we admire this method as it invites an error to be made too easily.

Another method would consist of placing the leaf on the milling machine and using the graduated dials of the machine, but this method seldom gives accurate results, especially after the serews have become worn through use. No doubt there are many more methods that could be mentioned, but we think that there is no method more accurate than the use of the buttons and indicator shown in Fig. 28.

INDICATING GAGE FOR USE ON MILLING MACHINE

The leaf of the jig is first "buttoned up," this being a familiar shop term used when applying the buttons to a piece of work. It is needless to go into details about buttoning up work, as that has been fully and thoroughly described in our treatise entitled "American Tool Making." After this is accomplished, the leaf is placed on the milling machine against an angle plate, to which it is held by clamps, as shown in Fig. 29. The indicator is then placed in the spindle of the machine and applied to a button,

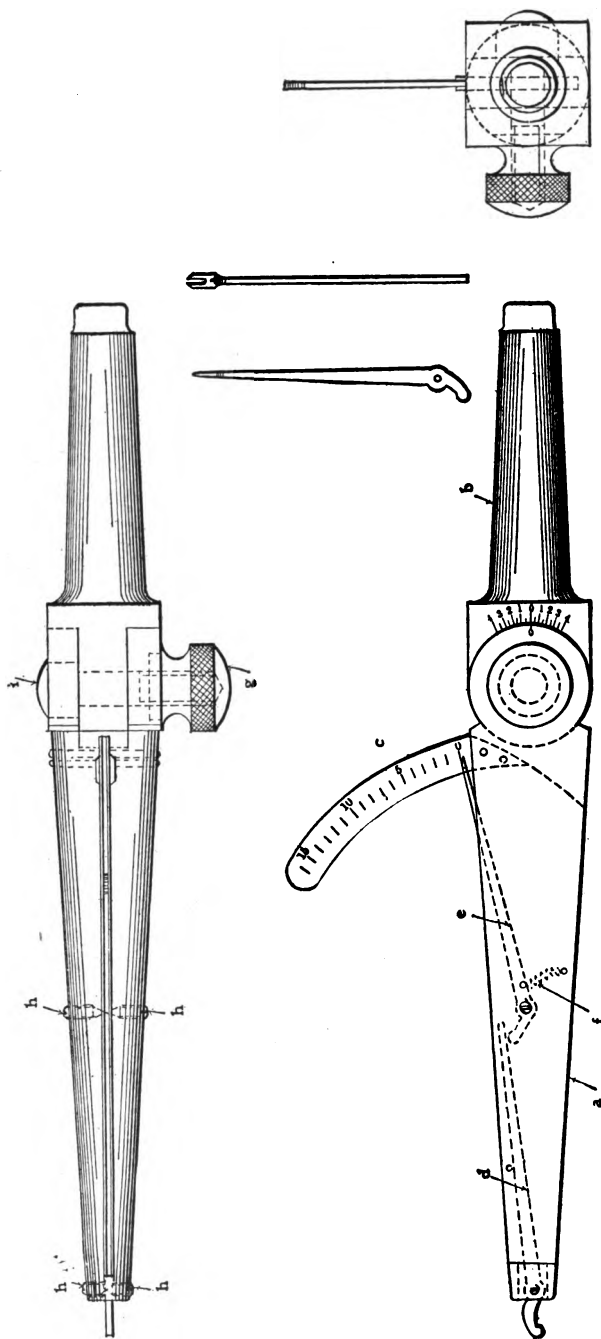


FIG. 28. — Indicator for Jig Work.

thus truing it perfectly with the center of the spindle, after which the hole is made with drill and boring bar.

The buttons most generally used are made as shown in Fig. 30. They are hardened, ground and lapped to fit a ring gage,

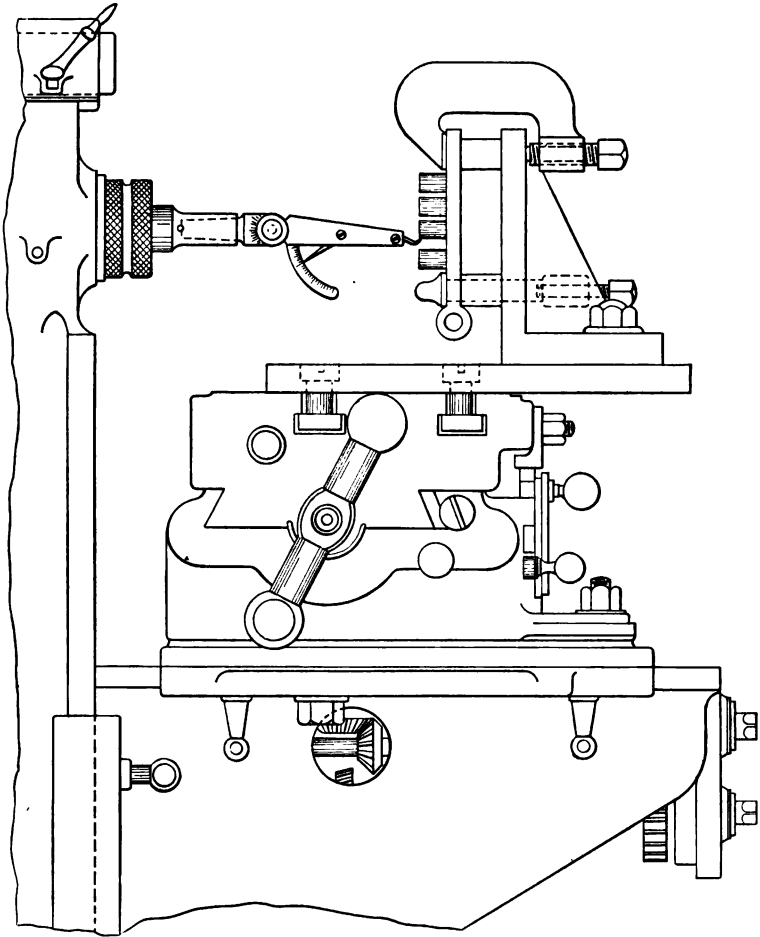


FIG. 29. — Use of Indicator in Milling Machine.

$\frac{1}{2}$ inch in diameter being a convenient size. As will be seen from Fig. 29, the angle plate rests on two special parallels, which in turn are bolted to the milling machine table. The object of letting the angle plate project over the side of the table on the

parallels is to permit the insertion of the tool in place of the indicator without disturbing the longitudinal position of the table, the tools being inserted by the use of the cross-feed screw.

The indicator is shown in Fig. 28. The shank *b* is fitted to a Brown & Sharpe small taper. On this shank is milled a tongue which fits into part *a*, and is graduated to facilitate setting the instrument to describe a circle of any diameter from 0 to 4 inches. When the zero mark on *a* is in line with a similar mark on *b*, the point of the indicator lever which comes in contact with the work will revolve on the center. There are eight graduations on each

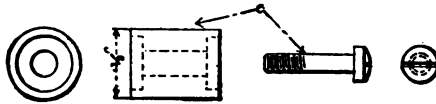


FIG. 30. — "Buttons" for Jig Work.

side of zero, each line giving $\frac{1}{4}$ -inch movement; that is, to describe a $\frac{1}{2}$ -inch circle the zero line on *a* would have to be set in line with the first line from the zero on *b*, and similarly the other figures on *b* denote the circle the point will describe. The tongue and groove joint is held firm by the knurled nut and bolt *g* and *i*. The body of *a* is slotted through its center to receive the two levers *e* and *d*, which swing on small pivot screws *b* having 60-degree points. A small and delicate spring *f* tends to hold lever *e* to zero on the graduated plate *c*, and also gives pressure against lever *d*, which in turn acts on the work. A little stop-pin above

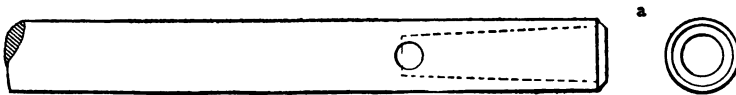


FIG. 31. — Shank for Indicator.

lever *d* holds the levers in position when at rest. A detail sketch of lever *e* shows the index to be forked to read against graduations on both sides of the arc plate *c*. This double graduation permits readings to be taken from either side, as the indicator turns over with the machine spindle. The indicator can be used to true up a hole as well as a projection, and it can also be used to good advantage in the drill press or lathe by placing the shank *b* into a round rod shown in Fig. 31.

We have also seen another method in use for locating work on the milling machine, which, however, is not as accurate as the

indicator. We refer to the arbor and bushing shown in Fig. 32. The arbor has its end ground, and lapped to the same size as the buttons, and a knurled ring is lapped out a nice sliding fit on the arbor. By placing the arbor in the machine spindle and bringing the jig button close to, and in line with it, so that the knurled ring will slip over the button, it is certain to bring both arbor and button in line. The trouble with this method lies in the failure of the arbor to always run true with the spindle. Should a bit of dirt get between the arbor and spindle, as is often the case, or should the spindle hole not be dead true, the arbor would not be true with the spindle, and an error would result in locating the work.

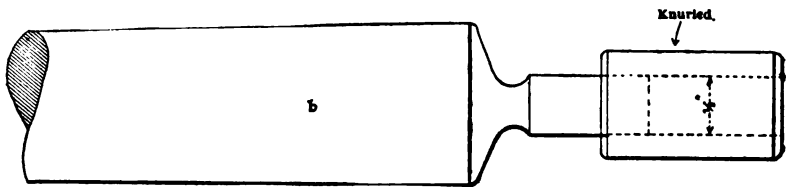


FIG. 32.—Arbor and Bushing for Jig Work.

VERNIER METHOD OF LOCATING WORK ON MILLING MACHINE

Another good method that can be used for accurately locating distances on the milling machine is shown in Figs. 33 and 34. Accuracy is obtained by using a Brown & Sharpe vernier caliper beam and vernier plate instead of the graduated disks. On the milling machine table *a*, and into the T-slot, which is intended for the feed-tripping studs, two bolts marked *b* are placed. They project out beyond the nuts which hold them in position about $1\frac{1}{2}$ inches, this outer part having been turned to the size of the root of the thread, and part of it flattened off to act as a resting-place for the vernier caliper beam *c*, which is held in position by two small straps and screws *f*. The forging *g* is held in position by utilizing the forward bolt and nut *b*, that serve to bind the swiveling part of the machine. On the top end of *g* the adjustable block *e* is held by a dovetail milled in *g*, and a slot and small binding bolt *i*. On this block *e* is secured the vernier plate *d*. As can be readily seen by running the table to and fro, and recording the measurements from the vernier, accurate measurements can be made. Accurate up-and-down measurements are made by a little extra device clamped to the column of the

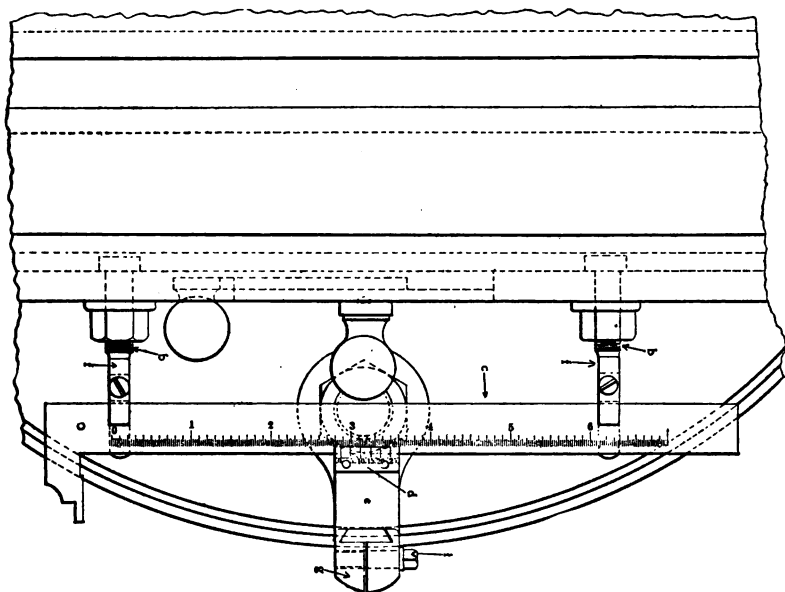
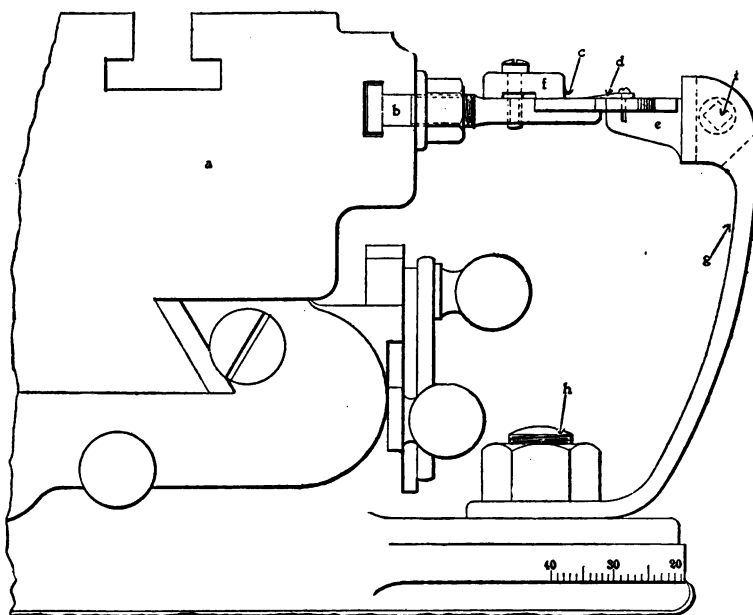


FIG. 33



FIGS. 33 and 34. — Milling Machine Practice.

machine and end measurement rods of such lengths as the job required, these rods being used between the knee of the machine and the part clamped on the column. One more little kink and this method is complete: By binding a piece of wire around *g*, having a loop above to hold a magnifying glass, easy and accurate reading is obtained. This last-named method is limited in range and accuracy by the length and accuracy of the vernier.

BORING MASTER GAGE PLATES FROM MODELS

Accurate tool and gage work is required in most factories at the present time, as the interchangeable system of manufacturing calls for it, especially where they require the most accuracy. It is always advisable to make the model first, then the gages, and last the tools. If tools and gages are made to models instead of drawings, as in many shops, it is absolutely necessary to make the gages first, in order that they may be perfect to the model, as fitting the model to jigs, fixtures and other tools may interfere with the accuracy of the model. There are some very good systems in some of our large shops for holding everything to standard. By one method the first step is to make a model machine which is as nearly perfect as mechanical skill can make it. When complete it is assembled to see if it is perfect in all details, and if found perfect it is taken apart and the gages are made to fit the parts in the most accurate manner. Three sets of duplicate gages are always made, one of which goes to the inspecting department, the second to the manufacturing department, and the third is held in reserve and only used as reference or master gages. This last set acts as a tell-tale to all mistakes, and as a standard for working gages or tools that may need renewal at any future time. Among these master gages are master plates, which serve to hold standard the size and location of a number of holes. A very neat way to make such master plates is as follows: Plane or grind a piece of steel so that it will be perfectly parallel and about $\frac{3}{8}$ -inch thick. Clamp it to the model piece opposite the side on which the holes in the model were located, with a thin piece of steel between model and master plate, so that when boring the holes in the plate no damage will be done to the model (see Fig. 35). Fit a piece of steel to the spindle of the lathe, as though it were to be a live center, allowing it to project

beyond the face-plate far enough to be turned off a perfect fit to the largest hole in the model. Care should be taken that the face-plate runs perfectly true. After turning the stud to a perfect fit for the first hole, the model with the master plate is slid on and clamped to the face-plate. The first hole in the master plate is then bored with an allowance of .002 for grinding after the master plate is hardened. For the second hole select the next size smaller so that the same stud will answer for all five holes, and proceed as before, care being taken to have the master plate securely fastened to the model to avoid any chances of slipping. After boring all holes in this manner the plate is ready

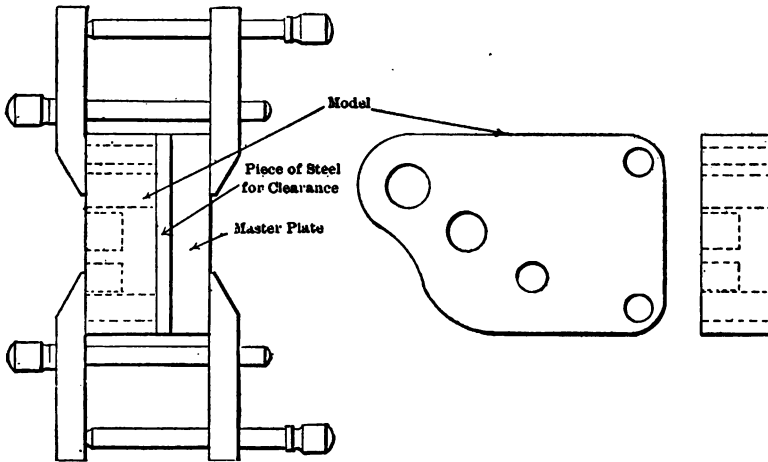


FIG. 35. — Boring Holes in Master Plate.

for hardening. After hardening the plate is replaced on the model and the holes are ground out to within .0003, which is left for the final lapping to size. Fig. 36 shows the work as swung in the lathe. Time may be saved by making the stud in two pieces, as in Fig. 37, thus saving the repeated fitting of the taper. The right-hand piece is soldered into the sleeve and turned off to form the stud, which, of course, is always turned off in position.

MAKING MASTER PLATES FOR WATCHES

In making master plates for watches, electric instruments, clocks and similar work, in which the holes in the side plates are to be held to a standard for the train of gears, and the holes are

too small to grind out after the master plate is hardened, it is good policy to bore such holes larger than the holes in the model, and after the master plate is hardened, grind the holes out with a diamond-charged lap used in the same manner as an internal emery wheel. The holes are then bushed, the bushing being hardened and lapped to the same size as the holes in model. A little piece of hardened drill rod is then placed in the spring chuck of a bench lathe, and ground to fit the hole in the bushing. The bushing is then slipped on and ground and lapped to a press fit

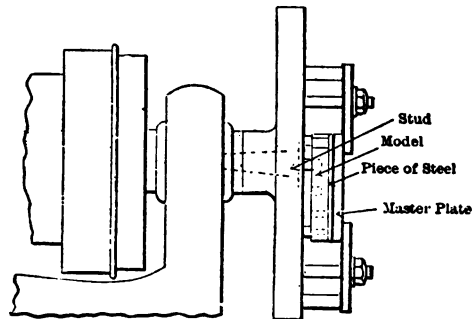


FIG. 36. — Jig Work in Lathe.

in the master plate, care being taken that the press fit is not so tight as to interfere with accuracy of plate.

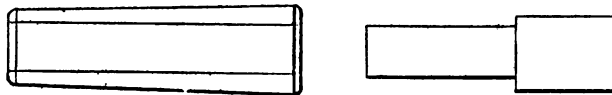


FIG. 37. — Stud for Jig Work.

USE OF GAGES AND INDICATORS IN ACCURATE INDEX PLATE MAKING

Making index plates seems but a small item, which no doubt it is, providing no accuracy is attached to it; but where accuracy is essential, it becomes quite a different task. It has fallen to a tool-maker's lot to make several such plates in which accuracy was required. His first plate was to have six notches for the index finger, and he attempted to make it in the milling machine, depending on a careful use of the dividing head; but when he proved it up he found an error of .005 in the spacing. Thinking

the dividing head might be at fault he tried another and found about the same error. Ultimately he tested seven heads but could not get an accurate plate, and came to the conclusion that he must contrive a more accurate method.

His first method gave very good results, but it necessitated the making of two plates and a lot of hand work. This method was as follows: Duplicate plates were placed on a hardened and ground arbor, and cut in the milling machine between centers with the most accurate dividing head at hand, one side of slot being radial and the other at an angle of 20 degrees with the radial line. After being milled they were placed on another arbor, which was a neat sliding fit in them, and their relative position changed, one being turned half way around. They were then clamped together, and with the aid of a knife-edged straight-edge, their accuracy was compared, when it was found that the slots did not register accurately. The high surface was then carefully scraped down, after which the plates were changed around to a different position, and the scraping was repeated, and so on until the two plates could be placed in any of the six positions and have their slots in perfect alignment with one another. This method gave one a perfect plate, but we did not like the making of two plates to obtain one, or the hand-work that was involved.

Our next plate was made as in Fig. 38, having hardened, ground and lapped tool-steel pieces *a* inserted and held in position by the $\frac{1}{2}$ -inch screws *b*, and by a perfect fit in the slots, which were in turn milled about $\frac{1}{4}$ inch deeper than the slots for the index finger *c*. One side of these lapped pieces stands perfectly radial, while the opposite side of the index slot is at an angle of 20 degrees. This style of slot assures the greatest possible accuracy, because when the index finger enters the plate the radial side of the slot stands perpendicular, thus not easily permitting any chips to lie on it, while the other side, being at an angle, has a tendency to force the radial side tight against the index finger. Should a chip get between the angular side and the index finger, it would not impair the accuracy of the divisions.

The method employed in making the plate, as well as many others with different numbers of slots, has proven very satisfactory. At the start the plate was milled out in the regular way on a milling machine, using the dividing head to space the

slots as accurately as possible. At this same setting the screw holes were drilled and counterbored so that each one would be in perfect relation with the others. The plate was then removed from the machine to await the finishing cut being taken, which

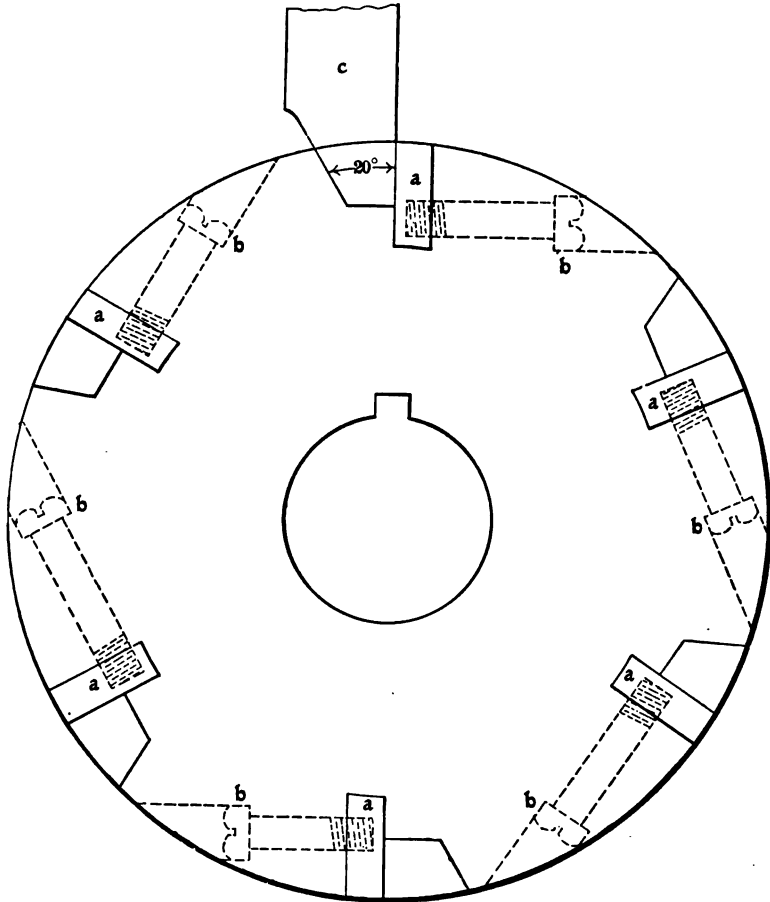


FIG. 38. — Index Plate.

would be but a few thousandths from each side of the slots into which the hardened plates fit. The machine was then prepared for the finishing cut as in Fig. 39. A dividing head was selected of which the worm could be released from the worm wheel, thus permitting the spindle to turn independently. Most of the latest

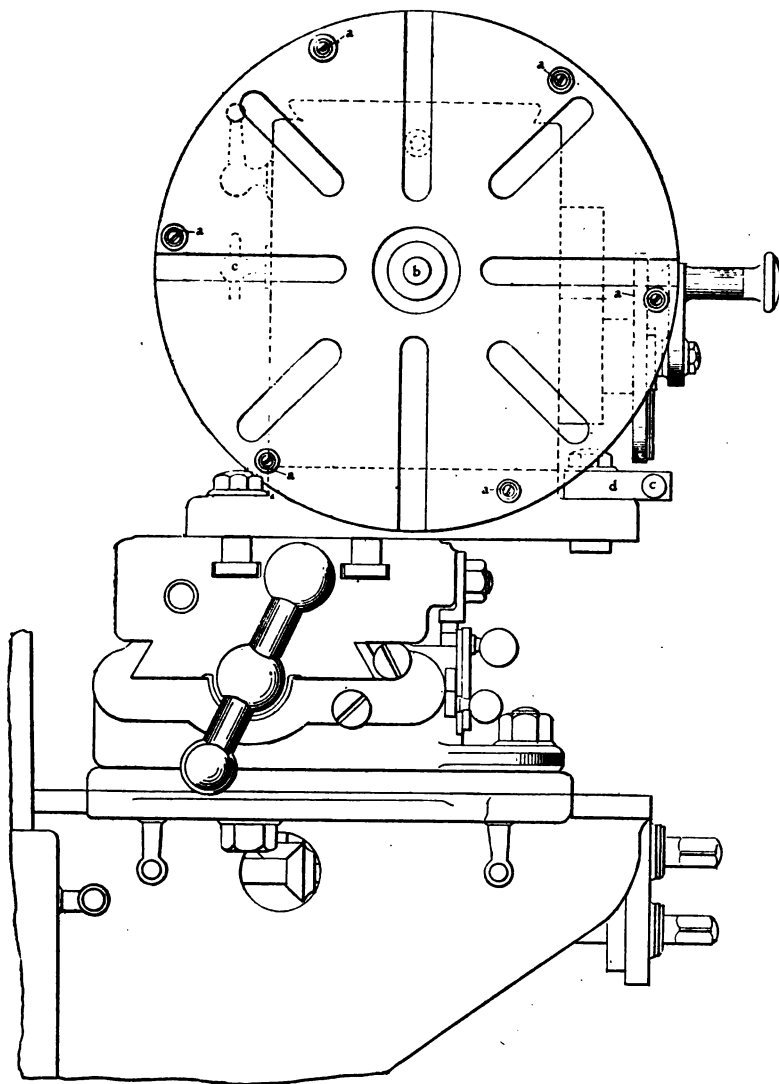


FIG. 39. — Machine Prepared for Finishing Cut.

style heads are constructed in this way, but if one of that pattern is not at hand, a regular head can be used with the aid of the wooden wedge tapped in between the face-plate and platen of the machine to hold it in position, the index crank being used to turn the spindle, but not for spacing purposes. A large face-plate was placed on the spindle of a larger diameter than the swing of the dividing head would admit, thus necessitating the use of the adapter which comes with every milling machine. Into this plate six holes were drilled, the spacing being done with the head itself. These holes were then tapped out to fit 10-32 screws, which in turn held "buttons," care being taken that all buttons were accurately to one diameter (hardened, ground, and lapped buttons fitting into a perfect ring gage are the only practical ones to use). These buttons will be seen in Fig. 39 marked *a*. A hardened and ground arbor *b* was then placed in the spindle of the head, on the end of which and projecting from the head is lapped stud *b*, of the same diameter as the buttons. Another piece *d* is held securely on the adapter with a bolt, and in turn carries another hardened and lapped stud *c* fitted to it, also of the same diameter as the buttons. This stud *c* is the stationary point from which all divisions are made.

The form of slot shown in Fig. 38 has another advantage, in that the wear is confined almost entirely to the beveled side where it does not impair the accuracy of the work. Moreover, the accuracy being determined entirely by the radial side, the precision work is confined to that side.

TESTING GAGE FOR INDEX PLATES

For testing up index plates the device shown in Fig. 40 is a very simple contrivance. It is composed of a cast-iron plate with a central locating stud, — for locating and swinging the index plate, a positive stop, — adjustable, *a* and the indicator *b*. The manner in which this gage is used is self-evident.

MAKING ANOTHER ACCURATE INDEX PLATE

Piece *A*, Fig. 41, we would grind parallel on both faces, then grind and lap the hole to size, and work from the hole and face of the index plate. This would detect the error in the blocks if out of parallel with the hole.

Piece *A* is mounted on stud *B*, which is a good fit in *A*. The angle iron has a hole for a loose fit for the end of stud *B*, which is threaded for a nut. The hole under block *d* allows one to see

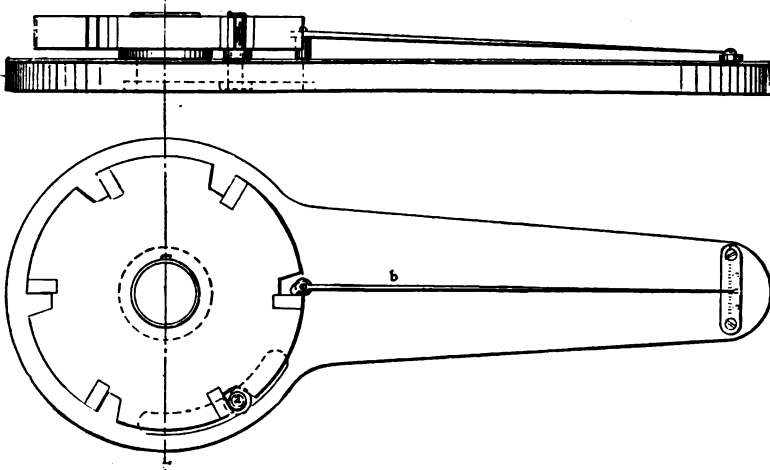


FIG. 40. — Gage for Testing Index Plates.

through when adjusting the blocks at right angles; piece *A* is clamped to the angle iron with a strap and screw that enters stud *B*; angle *C* is gray iron and narrow enough to allow to extend out from the sides to the ground.

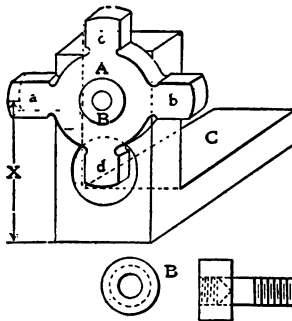


FIG. 41. — Making an Accurate Index Plate.

Fig. 42 is composed of a gray iron block *D*, and a piece of finished flat steel *E*, which is $\frac{3}{8}$ inch thick and worked out to the outline of piece *A*, Fig. 1, leaving plenty of space. The ends are beveled, hardened and ground back on face *e* about a quarter

of an inch. In lapping this edge, make it rounding, not sharp. Block *D* is finished on three sides of the sides; top, bottom, and the face piece *E* is attached to. This allows you to turn it over and prove both sides of the index blocks. The dimension x ,

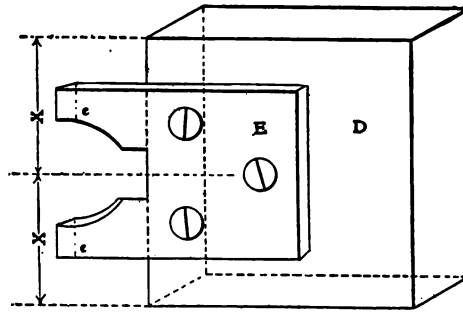


FIG. 42. — Index Plate Practice.

Figs. 41 and 42, should be close enough to allow the square to be used either side up.

Fig. 43 is the old principle of the reversible parallel for testing a square; parallel *F* swings on stud *G*, and is adjusted with the screws shown at the top, which are pivoted to swing out of the way to allow the parallel to be reversed end for end. To test

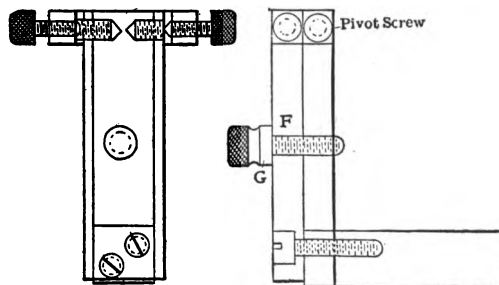


FIG. 43. — Index Plate Practice.

the square, you adjust the parallel to the square on one side; let the parallel remain in this position, place the square at the other side of the parallel, and it will show twice the error, if there is any. To test the parallel, reverse it end for end, then adjust to the square. It should fit the square on both sides of the parallel, or it will show twice the error on one side if not parallel.



With the index plate placed in position on the angle iron, Fig. 41, blocks *a* and *b* are leveled up, and have been found to have the least amount to be roughed off; these are ground off; then the index plate is revolved a quarter turn by using the square in Fig. 43 to square to the surface just ground, and *c* and *d* are ground to the same reading of the index wheel on the grinder or to a high gage. Now revolve the index plate another quarter turn, using the square again, and at the fourth quarter turn you have gone around all faces of your blocks. Now take a light cut to make up for the wear on the wheel from the roughing cuts, and go around without disturbing the setting of the wheel, and at the third quarter turn you can prove your square and setting with a micrometer. Your last surface should be parallel with the one under it. After going around the second time your blocks are divided equally each side of the center, but are too large. You have found approximately how much your wheel lost in size by the roughing cuts, so you can rough them down pretty close for the last roughing leaving just enough to finish with. This leaves nothing to guess at; the errors can be located and measured, all operations are tested before and after setting and clamping. The square is used on the index plate face as well as on the side of the blocks.

If we find that clamping in the way described distorted the plate, we should drill a hole through stud *B*, and use a bolt and nut instead of a cap screw.

SECTION II

ACCURATE TEST AND INSPECTION GAGES, ELECTRIC AND OTHER MEASURING MACHINES: TOGETHER WITH SPECIAL INDICATORS FOR INSPECTING DUPLICATE WORK.

INSPECTION GAGE FOR WALL THICKNESS

In Figs. 44 and 45 are test pieces for which the gages shown in Figs. 46, 47, 48 and 49 were made. These tools constitute a

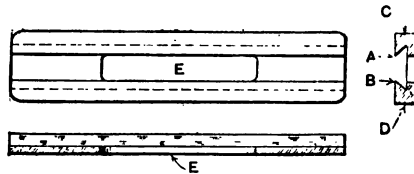


FIG. 44. — Work to be Tested.

set of test and inspection gages of decidedly interesting design, possessing adaptable features which may be used to advantage in similar gages for verifying measurements of small, accurately machined steel parts. All four of the gages are graduated to indicate variations down to .0005 inch.

The work, Figs. 44 and 45, for which the inspection tools were utilized, consisted of two parts of tool steel, which were machined to extremely accurate dimensions and were required to fit or assemble together perfectly. The part shown in Fig. 44, as may be seen, has a dovetailed channel milled in one side for its entire length, and has the web punched out to form a hole at *E*. This part, after all milling operations had been concluded, was hardened and tempered; the temper being drawn down sufficiently low to allow shaving the dovetailed surfaces to finish with "Novo" steel cutting tools, after which the sides and edges of the part were ground to limit sizes with a cup-shaped emery wheel in a

specially constructed grinder. It was after this operation that the two gages illustrated in Figs. 46 and 47, were used to determine the degree of interchangeability attained in the parts through the various concluding mechanical operations.

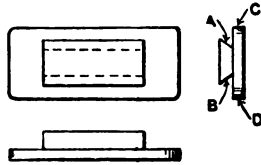


FIG. 45.—Work to be Tested.

The micrometer gage shown in Fig. 46 was used to determine the width of the part from the dovetail to the edges, or the wall, as is indicated in the lower view, in which is shown a cross-section of the work in position on the dovetail locating piece *L*. After

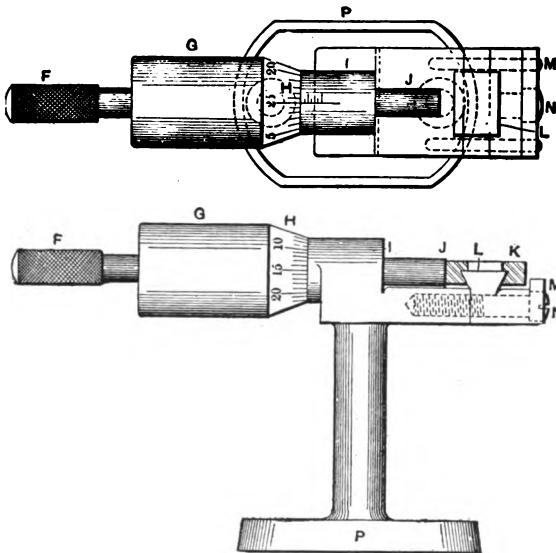


FIG. 46.—Micrometer Test Gage.

gaging one side in the manner outlined, the other side is inspected by simply reversing the work on the dovetail locator. The drawing of the gage is so clear and self-explanatory that a detailed description of construction will be unnecessary. *F*, *G*, *H*, *I*, and *J* comprise the micrometer portions, *L* is the locator, *M* is the

block upon which it is formed, *N* the fastening screw and dowels which fasten and locate it in position on the body of the gage; *P* is the base, and *O* the stem of the gage. Two flathead screws were used for fastening the gage to the work-bench. All locating and test parts of the gage were hardened and carefully ground and lapped.

TEST GAGE FOR WIDTH OF DOVETAIL CHANNEL

The micrometer gage illustrated in Fig. 47 was used for measuring the width of the dovetail channel in Fig. 44: that is,

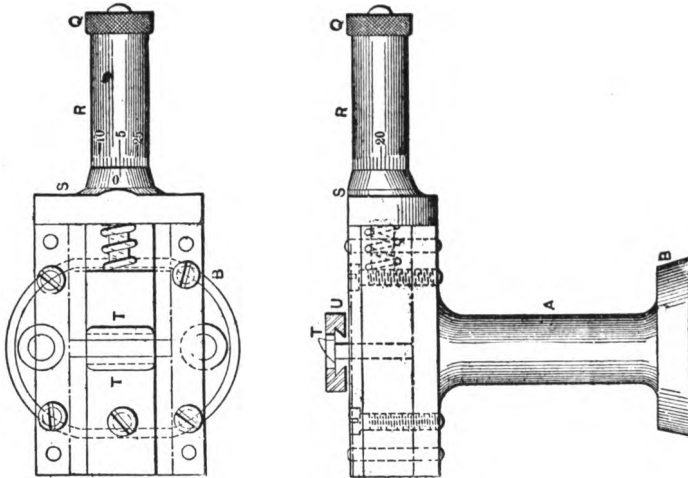


FIG. 47. — Micrometer Test Gage.

the distance between points *A* and *B*. This gage consists of base *B*, which is fastened to the work-bench when in use, stem *A*, two slides *T T*, which have raised angular-faced projections, which conform to the angle of the dovetail in the work, and the micrometer portions *S*, *R* and *Q*. The manner in which the gage is used to determine the width of the dovetail is clearly indicated in the view at right of Fig. 47, a cross-section of the work being shown in position. By revolving the barrel, by means of the knurled end *Q*, the slide *T* at the right moves back to allow removing or locating the work; while the revolving of the barrel in the opposite direction causes the slide *T* to move out and expand to the full width of the dovetail channel in the work. The

other side, *T*, is fixed. A light spiral spring, which is shown in the plan of Fig. 47, assists the slide to move back readily when the barrel is revolved and the work is removed or located.

It will be noticed that both gages described in the foregoing are simple in design and of comparatively inexpensive construction, when the rapidity with which the work may be handled and inspected in them, and the required accuracy of the tests, are considered. In case of wear in any of the precision parts of either gage, the error may be rectified by simply making suitable adjustments, provision for which may be seen in the drawings; thus no difficulty is experienced in maintaining the accuracy of the tools.

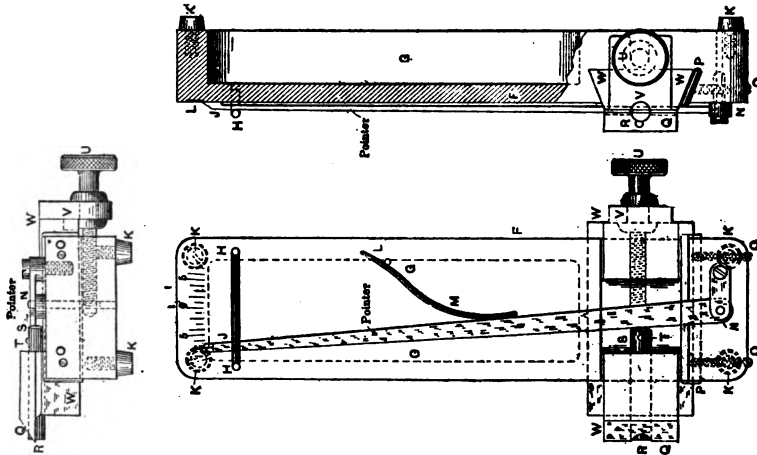


FIG. 48. — Test Indicator.

DECIMALLY GRADUATED GAGE FOR DOVETAIL SLIDE INSPECTION

In Fig. 45 is shown the dovetail slide which is required to assemble on the part shown in Fig. 44. This piece is also made of tool steel, is accurately machined all over, is shaved on the dovetail surfaces, *A* and *B*, and then ground on the back. It was for verifying the interchangeability of this part that the decimally graduated inspection gages shown in Figs. 48 and 49 were used for determining the exact amount of variation in the parts from the inner edge of the dovetail *A* and *B*, to the ground edges of the body portion at *C* and *D*.

The gage consists of a flat cast-iron base, *F*, cored at *G* and equipped with four steel legs, *K K K K*. *W W* is the test and

gage portion, and consists of a dovetail piece of tool steel which is fitted and gibbed into a channel in *F*, as shown by gib *P* and screws *OO*. This piece is milled away in the center so as to provide a clearance for the pointer *J*, which is pivoted on a small pin at *N*. The projecting end *Q* of *W* is hardened, ground and lapped to conform to the angle of the shaved dovetail surfaces of piece, Fig. 45; it is also drilled longitudinally in the center to accommodate the plunger *R*, which is fitted to "float" in the reamed hole. The rounded end of *R* at *S* rests against the edge of the pointer. Pin *T* in the end of the plunger prevents it from getting away, and the light spring *M* serves to keep the plunger out when the work is not against it. Knurled head screw *U*, spanned by yoke *V* and screwed into *F*, is utilized to correct any inaccuracies in the precision parts which occur through use and wear. The graduations for reading the tests are at *I*, at the extreme end of *F*, with the end *J* of the point matching them. When the pointer registers at 0, the work is up to the requirements; if it points at *T* at the left, the work is considerably too large; if it points at 5 on the right, the work is .0025 too small.

In using the gage it is placed on the bench before the inspector and the dovetail slide, Fig. 45, is located on it, with one dovetail edge resting against the angular face of *Q*, and the edge *D* resting against plunger *R*; thus, upon the inspector pressing down and in upon the work the edge forces the plunger *R* inward, and therefore causes the pointer to register the reading at *I*. A spanner of small diameter drill rod at *HH* acts as a guard for the pointer.

DECIMALLY GRADUATED SLIDE GAGE FOR DOVETAIL INSPECTION

In Fig. 49 we have another decimally graduated test gage, used in the inspection of part Fig. 45. It is used to determine the exact width of the dovetail portion, from *A* to *B*. A base of cast-iron is machined to accommodate the hardened and ground angular-faced pieces *I* and *F*. Piece *I* is fastened and located by screws *KK* and *JJ*, while piece *F* is left free to slide in the holder. It will be noticed in the plan view of this gage that the dovetail edges *G* and *H* of *I* and *E*, respectively, are at an angle of a few degrees with the dovetailed channel in the base; thus as the slide *F* is pushed forward the space between *G* and *H* decreases;

and as it is pulled back in the opposite direction the space increases; therefore by simply entering the work so that the dove-tail part rests between *G* and *H*, and then pushing the slide forward until the work is clamped or held tightly, a reading may be instantly made by noting the relation of the graduated lines with zero point *O* at *P*.

Although gages of the type described in the foregoing may appear quite simple and easy to construct, considerable skill and care are necessary in the grinding, lapping and graduating, in order to produce reliable precision instruments for the inspection of accurate work.

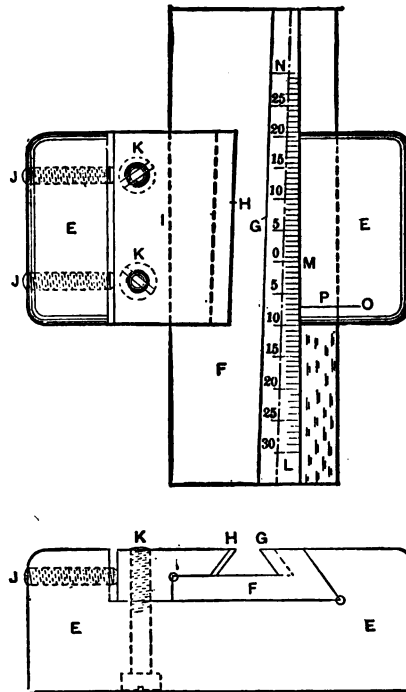


FIG. 49. — Graduated Slide Test Gage.

LARGE MICROMETER TEST CALIPER FOR MARINE ENGINE LINERS

The gage illustrated in Fig. 50 was used for gaging sixteen liners for four marine engines. The outside diameters of the liners — 40, 56, 77 and 108 inches — were turned for a press fit in the cylinders. There were, of course, four gages made, all like

the drawing. The size was taken from the cylinders with the ordinary gage made of a stick of wood with wood-screws in each end for adjustment. The gage in the drawing was then set for the outside diameter from the gage, enough larger to make a good press fit. As one can see from the drawing, the gages were made of ordinary iron pipe and fitting, and they cost but little. The top clamp of each gage was extended out and a hole was drilled through for a hook. From a column near the front of the lathe a rope was run up to a wooden bracket, the end of the bracket running out to the center of the lathe. The rope was

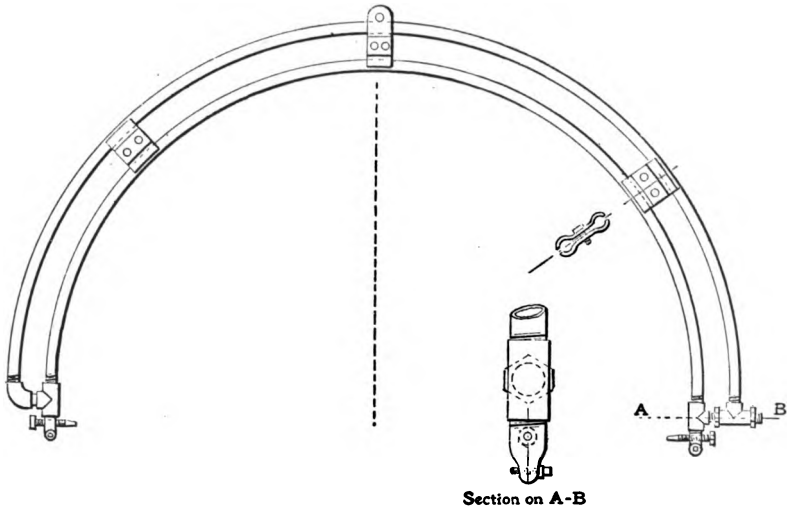


FIG. 50. — Gage for Marine Engine Liners.

run out to the end of the bracket and then down to the lathe with a hook on the end, which went through the eye in the top of the gage. The gage was then hoisted up until the adjustable screws were in line with the center of the lathe, and then fastened, so that to try the gage over the liner for size, a helper held one point on the line on one side, while the machinist raised and lowered the gage on the other side.

A TEST GAGE FOR LARGE DUPLICATE ROLLERS

The gage shown in Figs. 51 and 52 was used on a lot of cast-steel rollers for battleship turrets of the "Kearsarge" type. The rollers were to go between two tracks on which the turrets revolve, and had to be as near alike as they could be made, so the

weight of the turret and guns would be evenly distributed. Tap-bolts, shown in the end view Fig. 52, hold the V-blocks in place. They were put in before the V-blocks were planed, and then the surface plate, with V-blocks in place, was put on the planer and

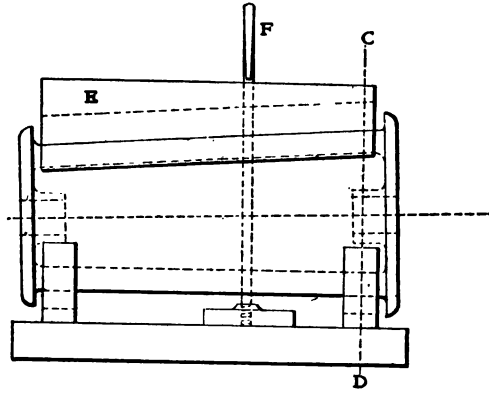


FIG. 51. — Test Gage for Duplicate Rollers.

set so that one V-block would be planed deeper than the other, and thus bring the bottom side of the taper roller parallel with the surface plate. The roller was set in the V-blocks, so the

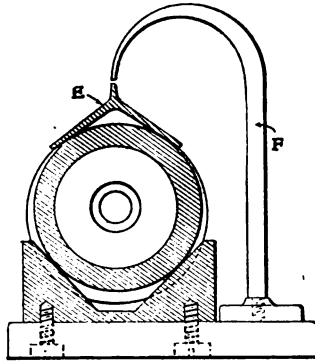


FIG. 52. — Test Gage for Duplicate Rollers.

distance between the inside of the flange of the roller and V-blocks at the bottom was equal at each end. The V-shaped piece *E* on the top of the roller was planed on the V-side to fit the taper of the roller. It was then placed on the sample roller, which was set in the V-blocks already planed, and the top edge of the V-piece was laid off with a surface gage and planed and

then scraped, the distance between the flanges of the roller and the ends of V-piece being kept equal. After the rollers were turned to size they were placed on the V-blocks, the block under the small end of the roller being one half the taper higher, so that the bottom of the roller would be parallel with the surface plate. Plate *E* was then placed on the roller and the gage *F*

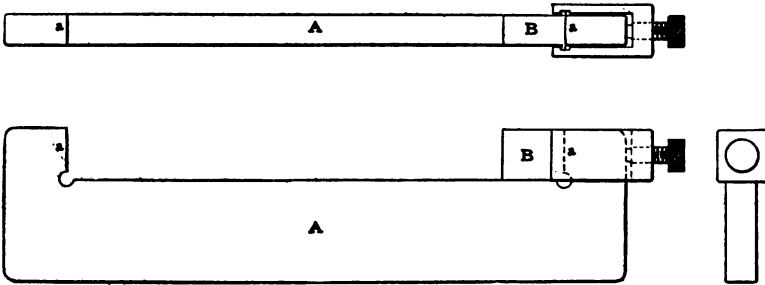


FIG. 53. — Simple Shop Gages.

moved along the edge of *E*. If there was any variation in height or in taper it would soon show it.

A SET OF SIMPLE SHOP GAGES

The illustration, Fig. 53, shows a plan adopted to provide an equipment of gages for end measurement. Outside gages *A* were made in exact inches between the shoulders *a a*, and the

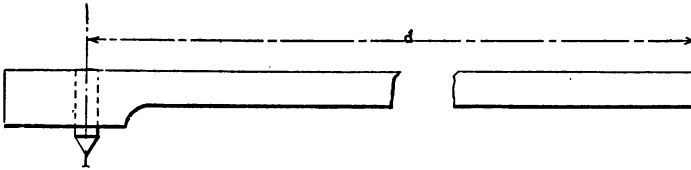


FIG. 54. — Keyseat Gage.

blocks *B*, of which there were two sets made, included sizes from $\frac{1}{8}$ to $1\frac{1}{8}$ inch by thousandths, and one $1\frac{1}{8}$ -inch block. The latter was used in place of a $\frac{1}{8}$ -inch block, which would have been too thin to hold with the clamp as made. Male gages to correspond were made of square steel and ground to length after hardening. By this method a large range of accurate gages was available at a comparatively small cost.

GAGES FOR LOCATING KEYSEATS

Figs. 54 and 55 and 56 show side and end views of scratch gages for scratching lines on chalked surfaces of the spindles before they are placed in the fixture, for locating the positions of keyseats in relation to the shoulders, it being found that when operators worked from drawings it was almost impossible to obtain uniform results.

The gages consist simply of light bars with hardened scratch-pins or points inserted at the proper distances from the ends,

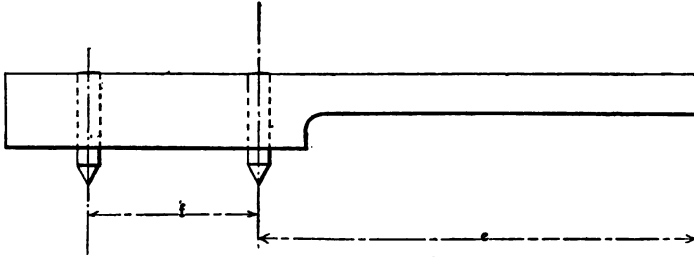


FIG. 55. — Keyseat Gage.

and each gage is lettered to indicate the particular size of spindle for which it is to be used.

Correct depth of keyways is obtained by making use of the graduated dial of the elevating screw of the milling machine.

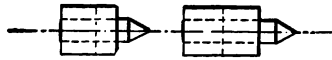


FIG. 56. — Keyseat Gage.

A NEW SYSTEM OF GAGES FOR THE PLANER

We present in Figs. 57, 58 and 59 a gaging appliance as used by the Bullard Machine Tool Co., Bridgeport, Conn. It is certainly unusual as well as highly meritorious.

The gage is intended for the three slots of boring machine tables, in which chuck jaws are inserted. For reasons of interchangeability as well as economy of production, it is obviously desirable that these slots be uniform, and this the device secures with a minimum of labor.

The boring mill tables to be slotted come to the planer with the lathe work completed, and with a concentric hole through the center which enables them to be mounted upon a post having a tongue fitted to the planer table slot in such a manner that the

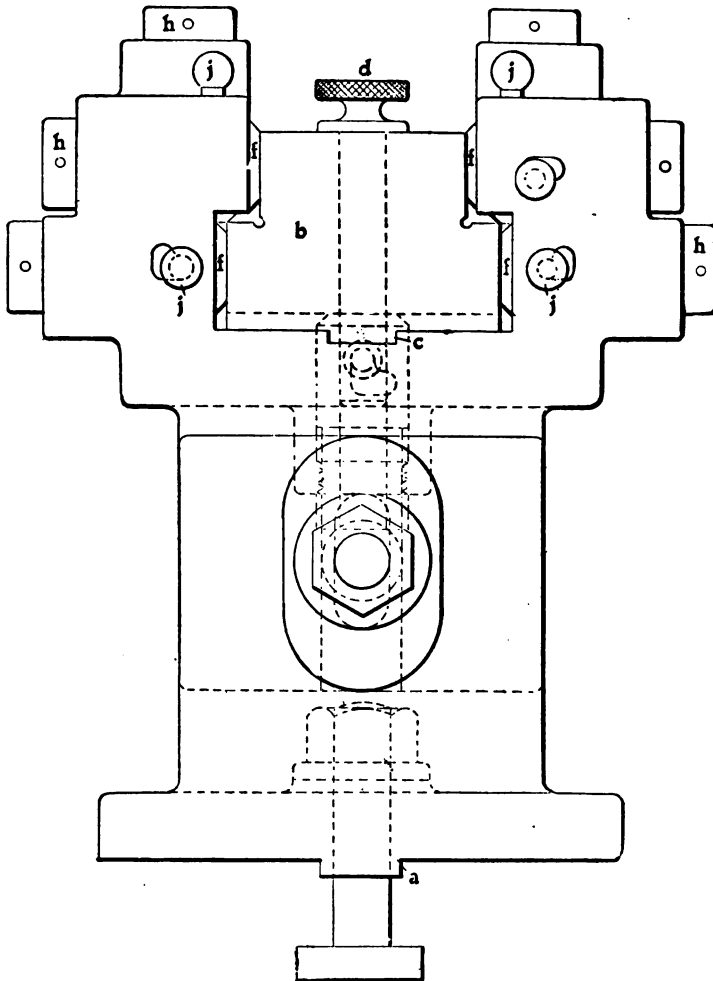


FIG. 57.— Planer Gage.

work shall be in line with the slot. On the front end of the planer table is bolted the bracket casting shown in the figures. This casting has a tongue at *a*, Fig. 57, fitting into the planer slot. The initial or plug gage for the chuck jaw groove is seen at *b*, Figs. 57 and 59, where its shape will be seen to be that of the groove to be made. It has a tongue *c* fitting into a corresponding groove in the bracket casting and is held in position by the knurled headed bolt *d*. The bracket is composed of two pieces arranged

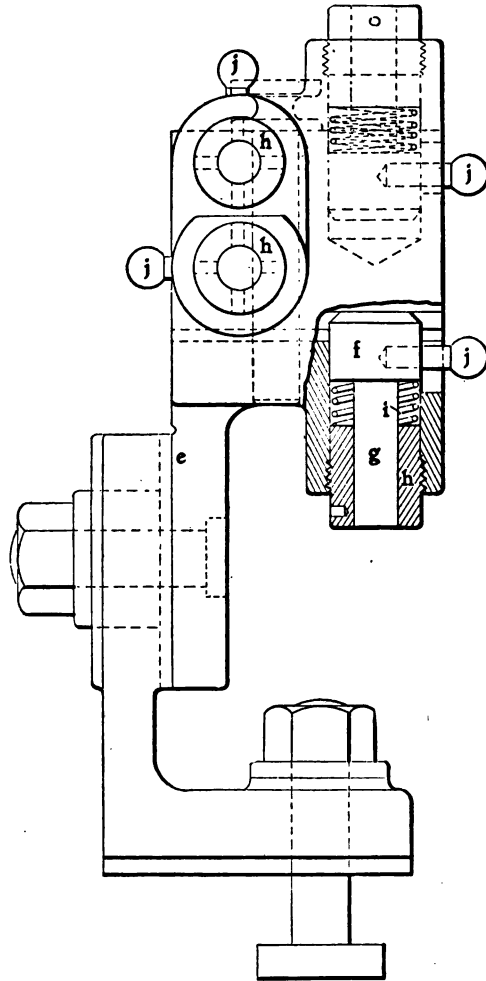


FIG. 58. — Planer Gage.

to slide vertically upon one another at *e*, Fig. 58, whereby the vertical adjustment of the gage as a whole is accomplished. The gage is surrounded by a series of beveled plungers *f*, one of these plungers being provided for each face of the plug gage which is reproduced in the boring machine table. The construction of these plungers is shown in Fig. 58, where they will be seen to have a tail *g*, sliding through a threaded bush *b*, while a coiled spring *i* forces the plug toward the gage *a*. It will be seen that with

the gage *a* inserted in the fixture the spring will force the various plugs to contact with the gage, and in this condition the bushes *b* are carefully adjusted until the tails *g* are exactly flush with them. The ends of the tails and bushes are carefully hardened and ground, and of course by applying the end of the finger to them the adjustment can be determined with a good deal of accuracy. A thousandth of an inch can easily be split into several pieces by this method.

With this adjustment made, the plug gage *a* is removed and the tool is inserted in the planer. When brought opposite the different plungers, the tools are adjusted until they press the

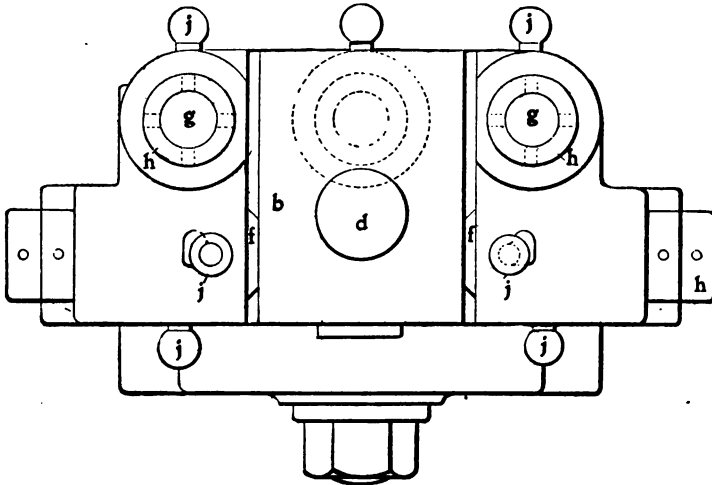


FIG. 59. — Planer Gage.

plungers back to such a point that the tails *g* and bushes *b* are again truly flush, when the tool obviously occupies the same position as the corresponding face of the original plug gage, and is correctly set for the finishing cut of the corresponding face of the slot to be made.

Connected with each plunger will be seen a ball-handled pin *j* projecting through a cam-shaped slot in the main casting. These pins enable the operator to draw the plungers back, and also to facilitate the placing of the plug gage in the fixture.

It will be observed that the fixture described not only sizes the slot, but positively positions it as well, and it would seem to be applicable to a considerable variety of duplicate work done on the planer.

THE TESTING AND COMPARISON OF END STANDARDS OF LENGTH

End standards of length, called gages, are tested and compared with one another by means of measuring machines, made by many engineering firms both in the United States and Europe. These machines are identical in principle, and differ little in form from the original one invented by Sir Joseph Whitworth. Their principle is that the gage rests against one jaw, fixed, of the machine, while the other jaw is moved forward by a micrometer screw until it touches the gage. Compression, more or less, of machine and gage, is required before any indication can be obtained that both jaws are firmly in contact with the gage. These machines will in the future be spoken of as mechanical touch machines, as distinguished from the new machines called electric-touch machines. In practice it has been found desirable to introduce some index of the touching, *e.g.*, a gravity-feeler, spirit-level, or the raising of liquid in a fine tube.

The weight of the gage, often large, should never — as is sometimes done — be supported by the grip of the two jaws; for then there is considerable end-thrust of the jaws, with consequent longitudinal strain in the machine, in addition to the vertical strain due to the weight of the gage. If the whole or part of the weight of the gage be supported by the jaws, though the latter be parallel to one another initially, they will not be so after being weighed. The errors which enter into the measurements made by these machines differ in kind and degree according to the nature of the gage. There are three kinds of gage.

BAR GAGES WITH PLAIN PARALLEL ENDS

Each jaw has a flat face, and each end of the gage has a flat face. Each of the four faces has defects in planeness and in being not strictly parallel to the other three. If in addition a gravity-feeler be used, it introduces extra errors. To admit so many errors of unknown amount in the measurement of gages may be permissible in present-day engineering practice, but it does not satisfy the demands of exact measurement. Thus to obtain accuracy, surface contact should be abandoned and point contact used, and these gages should be measured between two rounded points or spheres, in which case no assumptions are

made as to the perfectness or parallelism of the surfaces involved. For each point contact we require a more delicate means of perceiving contact than the mechanical one; hence the electric-touch method is employed. It has been developed by P. E. Shaw, of England, in a series of researches since 1900.

CYLINDRICAL GAGES

The flat faces of the jaws touch the cylinder with two line contacts at opposite ends of the diameter of the cylinder. Non-planeness and non-parallelism of the jaw-faces, as also imperfections in the cylinder, introduce errors, though these are less serious than for Bar gages. Thus for accuracy line contact should be superseded by point contact, the measurement to be made between lines or edges on the jaws, the lines being not parallel with the axis of the cylinder.

SPHERE OR BAR WITH SPHERICAL ENDS

The face of each jaw touches the sphere at a point. Since the jaw faces are imperfect, error can only be avoided by providing that the contact of the two faces with the sphere always occurs at the same places. Thus, for accuracy, contact may be made as usual between the flat faces of the jaws, if the surface be made true and contact be always at the same points on the flat faces.

From these remarks it appears that for each kind of gage, measurement should be made by point contact, the jaws to support no part of the weight of the gage, and the end thrust on them to be reduced as much as possible. The method described below fulfils these conditions, and has in addition the advantage of being more sensitive than the old method.

DESCRIPTION OF MEASURING MACHINE

The latest form of the machine is shown in Figs. 60, 61, and 62. In general appearance it is somewhat like the usual mechanical touch machines mentioned in the foregoing.

There are two headstocks and a table in the center, all resting on a massive cast-iron bed. The headstocks each carry micrometer screws and nuts with graduated heads, and these measure the gage, which rests on and is clamped to the table. The gage

being clamped to the table is set true with respect to the axes of the micrometer screws, by adjustments of the table. The left screw point is brought into electric contact with the gage; then the right screw point is brought into electric contact with the

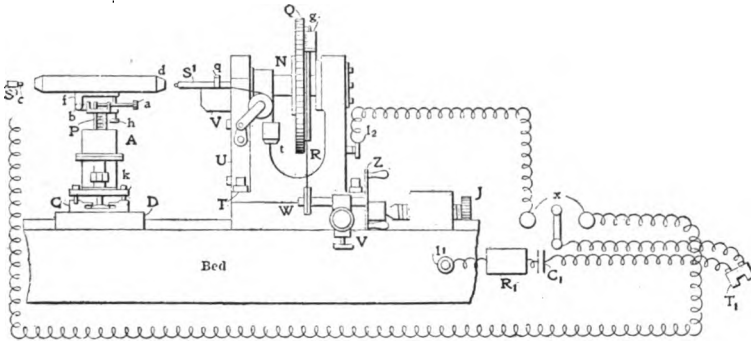


FIG. 60. — Measuring Machine.

gage, and when the current passes through the gage from one measuring point to the other, the two dividing heads are read. To turn the graduated heads the screw system is not actually

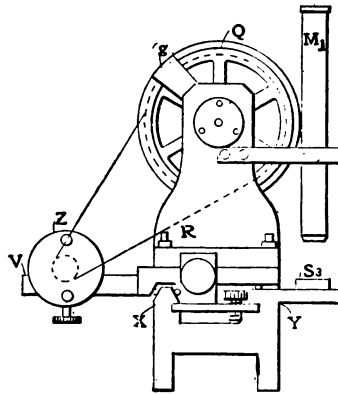


FIG. 61. — Measuring Machine.

touched by hand, but is worked by a hand-pulley and string, the former being attached to the base of the headstock, there being a large pulley on and concentric with the head. The left headstock is a replica of the right headstock; to save space, only the measuring point of the left headstock is shown. Gage *d* rests

on the table f and is clamped to it. The table top can be brought into any desired plane by two rotations, as follows:

The table is fitted with five adjustments, being movable through a small angle about a horizontal axis, and also through a small angle about a vertical axis, as well as adjustable in height. It can further be traversed either along or across the bed.

In Figs. 60 and 61 is shown a nut N working in bearings E_1 , E_2 , and having the screw S_1 in it. A steel cone n is screwed into the right end of the nut N , and bears against the stop m . There is a helical spring F which presses forward against the bearing E_1 , and back against the nut, forcing the cone n against stop m .

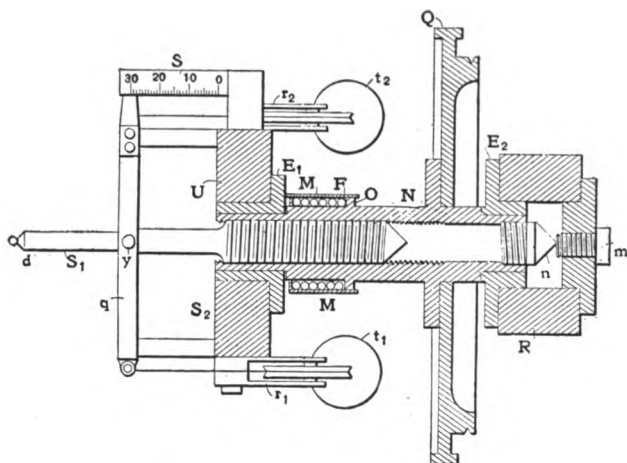


FIG. 62. — Measuring Machine.

The point of n lies truly in the axis of nut N , and the front face of m is ground truly plane, and by a special device is made accurately normal to the axis of the nut N . By this means, when the nut is turned it should be a true rotational motion, without any periodic to-and-fro translations along its axis, such as occur with the usual coned or flat bearings. Subsequent calibration of the screw shows how nearly this ideal has been approached. Fixed to the nut N is a graduated wheel Q , and a double vernier g is shown attached to the casting R . The wheel is centered true with the nut axis by means of the double vernier in the usual way. The casting R has a front part T , to which an upright plate U is screwed. This plate carries the bearing E , the bracket V on which runs the yoke a and pulleys r_1 , r_2 , Fig. 62.

The screw S_1 would rotate with the nut if free, but as the yoke q which runs on the bracket V is clamped to the screw, the latter acquires a simple translatory movement along its axis, in or out of the nut, according as the latter rotates right-or left-handedly. The screw spindle carries an index mark by which the position of the screw in the nut can be seen on the fixed scale S , Fig. 62.

In this micrometer system of rotating nut and translating screw, it is essential for accuracy that the nut have no translation and that the screw have no rotation. The former condition should be achieved by the cone end method of working; the latter, by making the yoke and bracket rigid and insuring by a weight that the former presses the latter with constant force. Backlash and looseness between micrometer screw and nut are minimized by the pull of weights t_1 and t_2 , Fig. 62, from which pulley strings pass over pulleys r_1 and r_2 to the yoke ends. By this means the screw is pulled back into the nut by a steady force.

The casting R is electrically insulated from the plate W by a mica sheet, and by having the screws which bind R and W bushed with ebonite. The base of plate W is grooved to fit the part X of the bed, and presses that part by four studs; one other stud presses on the flat part Y , Fig. 62. Thus the headstock rests firmly on the bed at five points of support, and has only one degree of freedom — along the length of the bed. Fixed on the side of W is shown a bar V , on which the hand-pulley Z can be pulled forward and clamped, so as to take up slack in the pulley cord.

The two micrometer screws and nuts were cut and ground with great care on the most advanced plan, and when examined under the microscope the screws appeared highly polished and regular. The calibration described below shows that there is a small periodic movement at each rotation of the nut, probably due to its bearings being eccentric with respect to its axis. But this movement is perpendicular to the line of measurement, and the resultant errors in the micrometry are of a lower order and probably negligible.

The screw heads are about 2 inches, and the nuts about 4 inches long, so that the screws do not leave the massive nuts at any point in the run. Steadiness in temperature of the screw is thus obtained. The screw diameter is 1 centimeter, the pitch

$\frac{1}{2}$ millimeter, the graduated head has 500 divisions, and the vernier reads tenths; so one vernier division corresponds to $\frac{1}{100.000}$ millimeter (or approximately .0000039) in the micrometry. The bed is 5 feet long and weight 200 pounds; it rests on three studs, two 1 foot apart under one neutral line, and one under the other neutral line. A voltaic circuit, consisting of a cell C_1 , a resistance box R_1 , switch X , and a telephone T_1 , are joined to a binding-screw l_1 on the bed, and to another binding-screw l_2 on each headstock. The switch is put to right or left, according as one wishes to make contact between the gage and the left screw, or between the gage and the right screw.

The micrometer microscope M_1 rigidly mounted on the right headstock, Fig. 61, is used for reading the standard invar scale S_3 . By this means, as in the Pratt & Whitney measuring machine, the end standards may be compared with line standards of length.

MATERIALS USED IN MACHINE

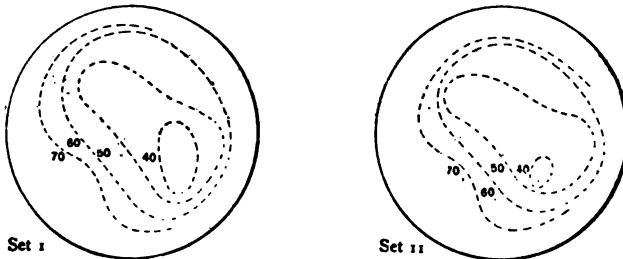
The bed is of cast-iron. Most of each headstock is of cast-iron, in one piece, but the front plates and brackets and the base-plates of the headstocks and table are of wrought iron. Brass is used for the nut bearings and for most of the table. The micrometer screws are of silver steel, and the micrometer nuts of bell metal, which is very hard. The part of the screw spindle projecting from the front of the nut is of first-grade invar. All caps and fittings on the screw end are also of invar. Since invar cannot be ground very true, the faces of the cups are of thin steel. The idea is that these projecting parts, being of small dimensions and necessarily uncovered, are more liable to temperature changes. The consequent errors in micrometry are small since the expansibility of invar is so minute. The terminal points of the screw spindle are beads of iridio-platinum, which, being hand-made and non-oxidizable, is the best substance for electric-contact work. The beads are continuous, with a short piece of iridio-platinum wire which was hammered into the hole drilled in the end of the invar.

MEASURING BAR GAGES WITH FLAT ENDS

These are measured in the electric-contact measuring machine between two points. The gage is put on the table and clamped.

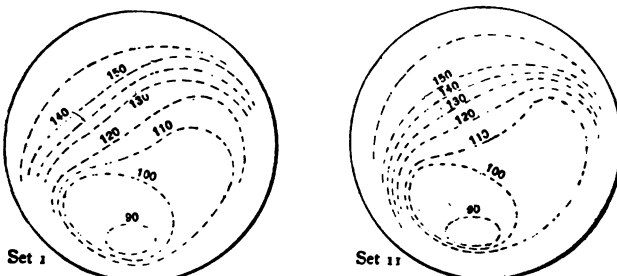
It must first be set so as to have one face normal to a screw axis by adjusting the table.

As will be seen from the contour curves, Figs. 63, 64, 65, 66, the flat ends are never true planes, but for the above purpose the gage is taken to be set when the contact readings on all points on a circle near the edge of the face are identical.



FIGS. 63 and 64. — Contour Curves of Gages.

The flat faces are roughly 6 millimeters across; the left screw point is brought into electric touch with the gage at the center of the left face, marked *I* in column *A*, Tables 1 and 2. The right screw point is then brought up to touch the right face, the circuit being now arranged to pass from the left screw through the



FIGS. 65 and 66. — Contour Curves of Gages.

gage to the right screw. The two micrometers are read as in columns *B* and *C*. Then the table, and the gage with it, are moved 1 millimeter to the left; the contact is now made at the place 2 in column *A*. The micrometer head readings are taken and entered in columns *B* and *C*, as before. The whole face, except near the edge, is thus tested in thirteen symmetrical places.

Results follow for two new gages, made by the best firms, in Tables 1 and 2. The numbers in columns *B* and *C*, and in other tables below, are those read on the micrometer heads, so that they give only comparative values from place to place, and would have to be changed alike to represent absolute values of the length of the gages. Column *D* is the sum of columns *B* and *C*; the larger the sum the less the thickness of the gage on the line in question. The small disagreement between the results for the two sets is shown in column Δ . The gage is well covered throughout the readings. For the 25-millimeter gage, Table 1, the errors arising for any one position lie between 0 and 0.4μ .¹ These errors can be attributed mostly to bad polish of the surfaces. Grooves are visible, and small changes in setting the surfaces would bring the measuring point now over a ridge, now over a hollow.

The errors in reading the micrometer can be ignored, for if any observation be repeated before the gage is moved, the difference in the reading never amounts to more than 0.1μ , generally less. Thermal expansion may produce a small deformation, since about three quarters of an hour elapses between a reading in Set I and the corresponding one in Set II. (See Tables, pp. 69 and 70.)

The difference in the gage thickness in different places amounts to 3.6μ . To show the nature of the gage, contour figures are drawn, one for each set. These curves are not contours for one surface in the usual way, but represent the joint effect of the two end faces of the gage.

In the 150-millimeter gage differences are slightly more, — 0.1μ to 0.5μ (thermal expansion exercises more influence for long gages) than for the 25-millimeter gage. But the difference in the gage thickness from place to place amounts to 5.8μ . The contour figures are given. The faces are not normal to the length of the gage, and no reading can be taken at places 5 and 9; when in these positions one screw end touches the gage, the other screw end does not make contact on the other face, but, if continued, would meet the gage on its side. The actual length of this gage was found to be, at 18.5 deg. C. , 150.0332 millimeters, and 150.0325 millimeters in two distinct evaluations, taken at place 1, Table 2.

¹ Micron, the millionth part of a meter, or $\frac{1}{25400}$ of an English inch, represented by the Greek letter μ .

TABLE 1. — 25-MILLIMETER GAGE

A	SET I			SET II			$\Delta =$ $D' - 0$
	B	C	$D =$ $B + C$	B'	C'	$D' -$ $B' - C'$	
1	116.5	147.9	264.4	117.6	146.9	264.5	+ 0.1
2	117.5	146.3	263.8	117.4	146.7	264.1	+ 0.3
3	117.3	146.9	264.2	118.2	146.3	264.5	+ 0.3
4	117.9	147.7	265.6	118.7	146.9	265.6	0.0
5	117.	149.9	266.9	118.	148.9	266.9	0.0
6	117.	147.4	264.4	117.5	147.1	264.6	+ 0.2
7	117.8	147.6	265.4	118.4	147.3	265.7	+ 0.2
8	116.6	147.5	264.1	117.9	146.6	264.5	+ 0.4
9	118.	147.5	265.5	118.1	147.7	265.8	+ 0.3
10	118.	147.5	265.5	117.7	147.9	265.6	+ 0.1
11	117.7	146.	263.7	117.3	146.6	263.9	+ 0.2
12	118.9	148.5	267.4	119.5	147.9	267.4	0.0
13	119.	147.5	266.5	119.6	147.1	266.7	+ 0.2

TABLE 2. — 150-MILLIMETER GAGE
THE UNITS ARE MICRONS

A	SET I			SET II			$\Delta =$ $D' - 0$
	B	C	$D =$ $B + C$	B'	C'	$D' -$ $B' - C'$	
1	395.	96.2	491.2	395.	96.	491.	- 0.2
2	397.	93.8	490.8	396.	94.5	490.5	- 0.3
3	396.	94.9	490.9	395.	95.5	490.5	- 0.4
4	398.7	93.5	492.2	398.	93.9	491.9	- 0.3
5							
6	394.	98.7	492.7	396.	96.6	492.6	- 0.1
7	396.	95.5	491.5	396.	95.0	491.	- 0.5
8	398.3	96.7	495.	399.	95.5	494.5	- 0.5
9							
10	396.	93.7	489.7	396.	93.4	489.4	- 0.3
11	397.	93.4	490.4	397.5	92.8	490.3	- 0.1
12	398.	91.7	489.7	399.	90.5	489.5	- 0.2
13	396.	92.9	488.9	396.	92.7	488.7	- 0.2

TABLE 3.—THREE-QUARTER INCH CYLINDRICAL GAGE
THE UNITS ARE MICRONS

DEGREES	CENTI- METERS FROM END	SET I			SET II			$\Delta = D' - D$
		A	B	$D = A + B$	A'	B'	$D' = A' + B'$	
0	0.5	236.9	197.8	434.7	233.5	201.2	434.7	0.0
	1.0	242.0	192.6	434.6	238.0	196.7	434.7	+ 0.1
	1.5	241.1	193.5	434.6	238.0	196.7	434.7	+ 0.1
	2.0	234.4	199.8	434.2	231.0	203.1	434.1	- 0.1
	2.5	226.6	207.6	434.2	233.0	211.2	434.2	0.0
	3.0	235.3	199.0	434.3	231.0	204.2	434.2	- 0.1
45	0.5	237.6	197.0	434.6	231.0	203.6	434.6	0.0
	1.0	233.0	191.7	434.7	238.0	196.5	434.5	- 0.2
	1.5	241.0	193.4	434.4	236.5	197.8	434.3	- 0.1
	2.0	234.0	200.2	434.2	230.0	204.0	434.0	- 0.2
	2.5	220.0	208.3	434.3	223.0	211.2	434.2	- 0.1
	3.0	233.0	201.3	434.3	230.0	204.1	434.1	- 0.2
90	0.5	234.0	200.6	434.6	230.0	204.6	434.6	0.0
	1.0	240.0	204.4	434.4	236.0	198.5	434.5	+ 0.1
	1.5	240.0	194.3	434.3	237.0	197.5	434.5	+ 0.2
	2.0	233.5	200.8	434.3	230.0	204.2	434.2	- 0.1
	2.5	225.0	209.1	434.1	223.0	211.2	434.2	+ 0.1
	3.0	233.0	201.1	434.1	229.0	205.2	434.2	+ 0.1
135	0.5	234.0	200.5	434.5	231.0	203.4	434.4	- 0.1
	1.0	240.0	194.6	434.6	238.0	196.5	434.5	- 0.1
	1.5	240.0	194.3	434.3	236.0	198.3	434.3	0.0
	2.0	233.0	201.0	434.0	229.0	205.2	434.2	+ 0.1
	2.5	225.0	209.2	434.2	221.0	213.3	434.3	+ 0.1
	3.0	234.0	200.3	434.3	229.0	205.2	434.2	- 0.1
180	0.5	235.0	199.7	434.7	225.0	202.6	434.6	- 0.1
	1.0	237.8	196.8	434.6	238.0	196.5	434.5	- 0.1
	1.5	239.0	195.4	434.4	238.0	196.4	434.4	0.0
	2.0	232.0	202.1	434.1	230.0	204.2	434.2	+ 0.1
	2.5	224.0	201.2	434.2	222.0	202.2	434.2	0.0
	3.0	232.0	202.2	434.2	230.0	204.2	434.2	0.0

MEASURING CYLINDRICAL GAGES

These are measured between lines or edges. The screw ends have cylinders or edges mounted perpendicular to the screw axes. A preferable method is to work between the screw points, and to move the table carrying the gage up and down past the screw points so as to just establish electric touch in passing. In this way the straight lines mentioned above are virtual lines due to the passage of the measuring points past the gage.

Before commencing measurement the axis of the gage is set perpendicular to the screw axis. Put the gage on the table, its axis being horizontal and across the length of the gage. Move the gage by the table till its other end makes contact with the left screw end. If the two contacts have identical micrometer readings, the gage is set.

The results for a $\frac{3}{4}$ -inch gage are shown in Table 3.

Readings are made along the gage at six places from 0.5 to 3 centimeters from one end. After one set of six readings the gage is rotated on its axis to position 45 degrees, 90 degrees, 135 degrees and 180 degrees from the original one, and for each position six readings are taken, as before.

Set I takes about three quarters of an hour, and is completed before Set II is commenced; corresponding measurements are in one line. In no case do the results of the two sets differ by more than $\pm 0.2\mu$.

The gage is a very good one; the differences in various places are not more than 0.7μ , though there is a distinct tapering in every position, the handle end being thickest. There is a slightly different angle of taper in the different positions. The 180-degree position results are almost identical with those for 0-degree position, as they ought to be.

SENSITIVE ATTACHMENT FOR MEASURING INSTRUMENTS

We have often wondered why the system of sensitive measurement, such as is found on a Bath indicator, is not more extensively used. No matter how finely and accurately micrometers and verniers may be made, dependence must in all cases be placed on the sensitiveness of a man's hand to obtain the exact dimensions of the piece to be measured. In order to overcome this

difficulty and eliminate the personal equation in the manufacture of duplicate and interchangeable parts, we have tried the sensitive attachment to the micrometer shown in Fig. 67, and found it of much value.

The auxiliary barrel *A* is held to the anvil of the micrometer by means of a thumb-screw *B*. In the inside end of the barrel is a secondary anvil *C*, the base of which bears against the short arm of the indicating lever *D*. The action will clearly be seen by reference to the cut. The micrometer is so set that when a gage, *G*, of exact size is placed between the measuring points, the long arm of the indicator stands at the 0 mark. If the pieces being calipered vary in the least from the standard size, it will be readily noted by the movement of the pointer. Hard rubber spheres turned from rough were found to vary from 3 to 5 thousandths after having passed the inspector's test with an ordinary

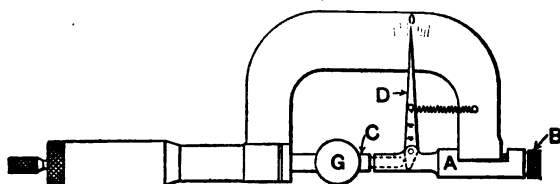


FIG. 67. — Special Micrometer.

micrometer. With this attachment the inspector's helper could detect very minute variations from the limit size. The same device was used to gage the size of all brass disks about half the diameter of the rubber spheres, and in fact anything within the limit of the micrometer can be made to show to the naked eye variations as small as a ten thousandth. Considerable trouble was experienced with a pair of small brass miter gears, because of the difficulty of getting the outside diameter just right. Inasmuch as they were finished on a screw machine, some of the holes were not concentric with the face, causing the gears to bind. Fig. 68 shows a gage which was quite inexpensive and at the same time showed up the slightest inaccuracy.

A DEVICE FOR TESTING GAGES

In some shops certain thin bow-back gages are used, which will get out of true if accidentally dropped, or if a light rap is

given to the machine. When it happens the inspector will take a two-foot rule, try the gage, and finally send it to the tool-room for repair. Here the tool-man tries it on a steel rule, gets the mate to it, and adjusts them by peening. We have here in Figs. 69 and 70 a micrometer caliper which was designed several years ago for the purpose of testing gages such as these.

The caliper will test both inside and outside gages. Piece *A*, Fig. 70, can be adjusted to any inch on the bar by loosening thumb-nut *B*, and the desired inch can be located through the opening *C*. The adjustments for thousandths can be taken from the micrometer adjustment at the other end. *D*, Fig. 69, is a support for the bar and can be removed along the bar when necessary. This caliper can be used to set inside and outside calipers.

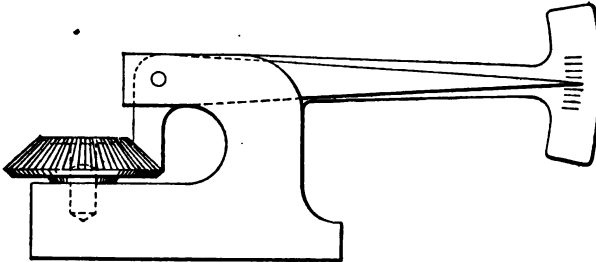


FIG. 68. — Bevel Gear Gage.

A TESTING TOOL FOR FINE WORK

The sketch Fig. 71 shows a very fine tool for testing work to .0001 inch and less; you can measure much closer with this than with micrometers. The jaws are 1 inch long, are .001 inch farther apart at the point than at the back, and the fixed jaw is graduated in tenths on one side; thus variations of .001 inch or less may be detected in work placed between the jaws. Say we have a piece to test, like the one shown in the sketch, to see if its faces are perfectly parallel; move the jaws down on the work, say, 4, 5 or 6, and try all four corners and see if they come to the same point. If they do, the piece is exact. If not, whatever is out is plainly shown by the graduations. Any one with fine work to do will appreciate this tool. We thought we could grind them close enough with our micrometers, but we could not, so we made one of these tools and it worked admirably. You will be surprised to see how closely you can measure with it. This tool must be hardened and ground all over.

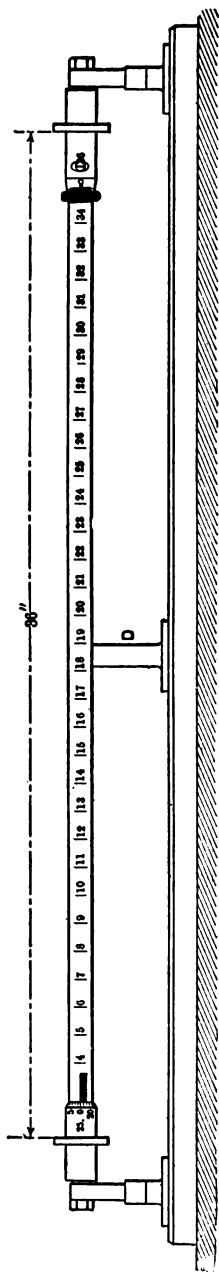
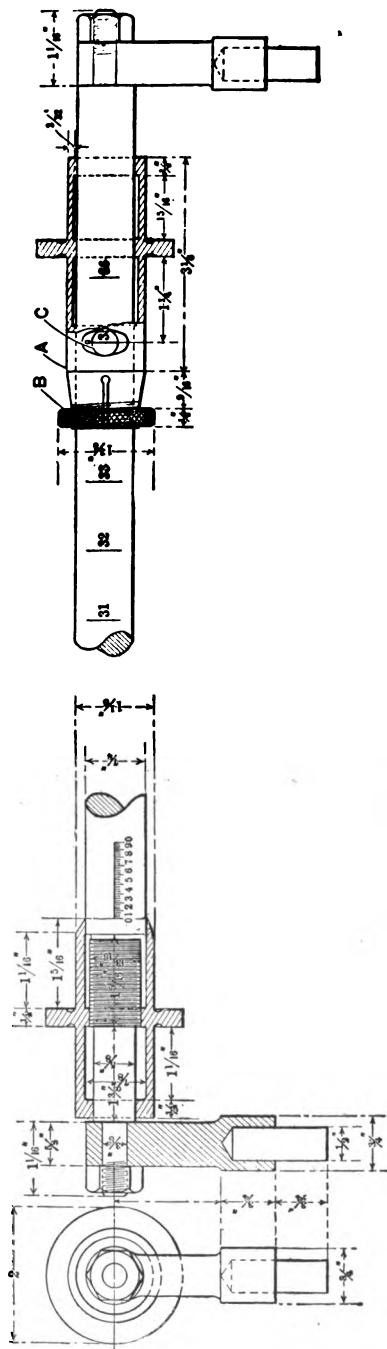


FIG. 69. — Micrometer Caliper for Gage Testing.



A ROLL GAGE

The engraving, Fig. 72, shows a gaging implement which has been devised especially for gaging rolls, such as are used in the cold rolling of sheet metal, where, as our readers know, very great accuracy is often required. The gage consists essentially of a curved plate, which rests on top of the roll to be gaged. Rising from the center of this plate is a cylindrical standard having graduations upon it, and attached to a piece sliding upon this standard there is a swinging bar which is graduated and carries two measuring jaws. The one at the left is plain and solid, while the one at the right is made of an open framework, and with a contact piece attached to the short arm of a multiplying lever which is connected to the shorter arm of a second

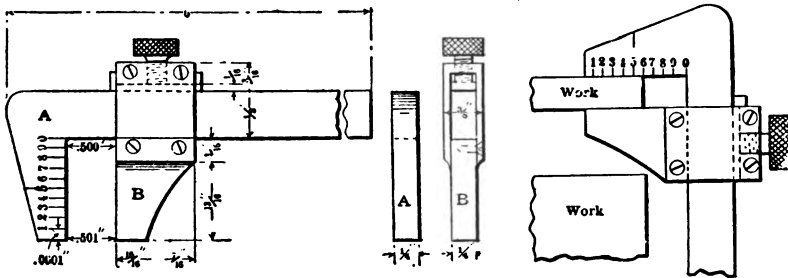


FIG. 71. — Tool for Accurate Testing.

multiplying lever, which indicates variations of diameter on the curved scale shown above, the graduations of this scale being to half-thousandths. In using the gage the horizontal beam is set on the standard to the nominal diameter of the roll, as indicated by the graduations on the standard. The left-hand jaw is set also to the graduation corresponding to the nominal diameter of the roll and the right-hand jaw, so that at the beginning of measurement the point will indicate zero. Then when the gage is moved endwise upon the roll, any variation of diameter is shown upon the graduated scale. The horizontal arm is free to swing in a vertical plane during this process. Usually the lower roll is not truly cylindrical, but is largest in the middle, there being a straight or cylindrical section in the middle with slightly tapering sections at each end, the result being that when pressure is put on the rolls, the upper line of the lower roll is practically

straight and the metal is rolled to practically uniform thickness. This gage is especially adapted for indicating when the designed taper has been secured; the grinder's experience telling him what the proper taper is. The object of making the flat-hand jaw solid is that it may be the heavier, so that placing the finger

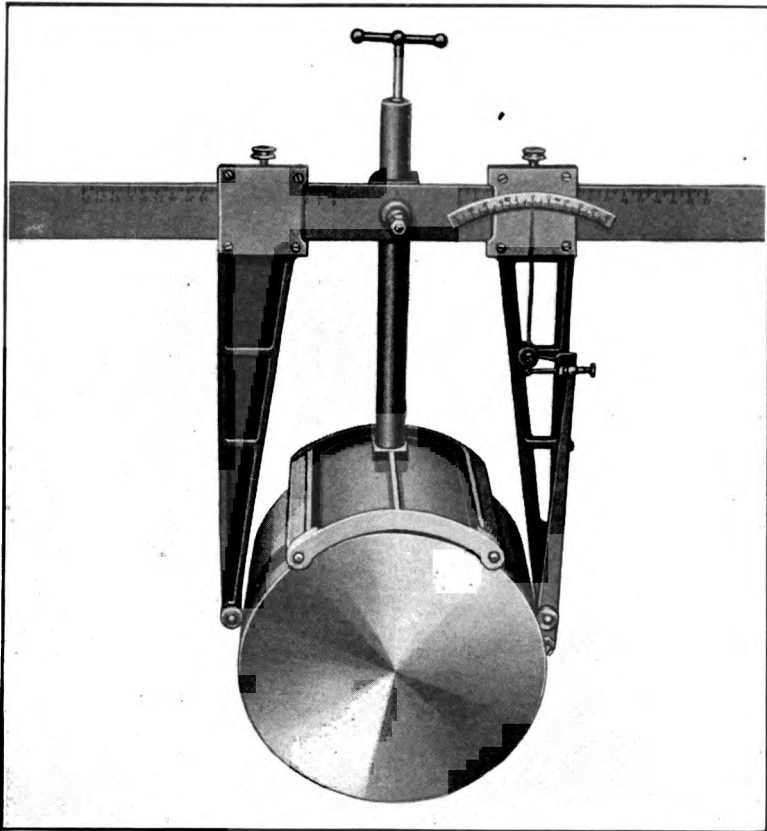


FIG. 72. — Instrument for Gaging Rolls.

upon the horizontal bar at the right and swinging this bar slightly, the contact points are made to pass over the largest diameter of the roll. All the contact pieces are made cylindrical, but do not turn freely. They can, however, be turned by loosening the screws so as to bring fresh contact surfaces in use when the instrument has become worn.

A NEW ENGLISH TYPE OF UNIVERSAL LIMIT GAGE

Fig. 73 shows the Newall working gage with its adjusting dial and zero in position. The pair of contact points at the left is fixed in position, but the pair at the right is adjustable by a screw-driver. One of the opposing pairs of points is intended for the

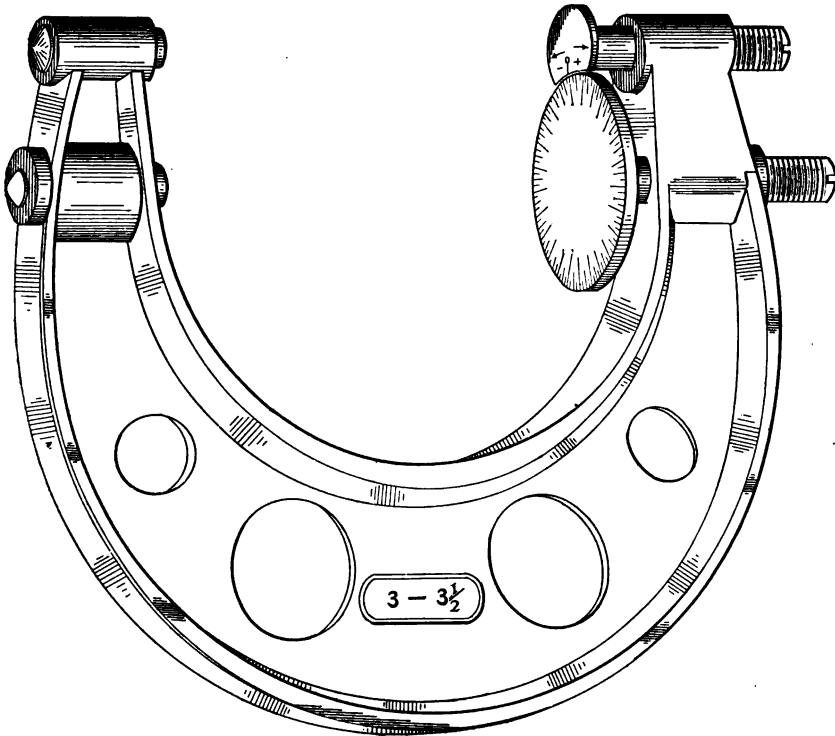


FIG. 73. — English Universal Limit Gage.

lower and the other for the upper limit of the piece for which the gage is to be adjusted. When adjusting the gage both pairs of points, with dial and zero removed, are first adjusted to true size by a standard plug gage — a set of such plugs being all that is required in the way of fixed gages. The setting dial and zero — shown to larger scale in Fig. 74 — are then slipped over the contact points as shown in Fig. 73, and by a screw-driver the point which carries the dial is adjusted the required amount above

or below the standard to give the lower limit of size, and is then locked. The dial and zero are then reversed and the outer point is adjusted to the upper limit of size. The fit of dial and zero on the screw points is by a taper, such that pressure with the thumb will fasten them in position securely enough for the purpose. The dial reads both ways from zero, in order to provide for setting the gage above the plug size for a forced fit, or below it for a running fit.

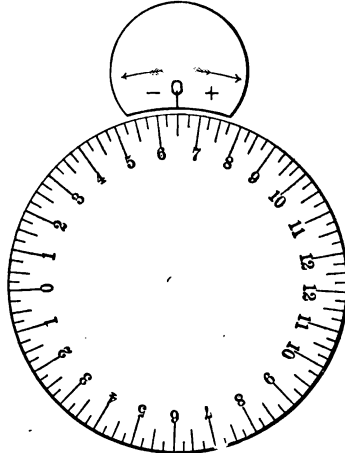


FIG. 74. — Dial of Limit Gage.

GAGE FOR MEASURING HAIR LINES ON TYPE FACES

The drawing, Fig. 75, shows a device for measuring hair lines on the faces of type, which we made a few months ago for a type-making firm. We take it for granted that it is all right and fills the bill, as we have never heard from it since it was finished. The sketch is drawn from memory, and is only intended to show the principle of it.

A is a block of tool steel made in the shape shown and worked up true with the hole, which receives the adjusting screw *E* and micrometer screw *G*, also the rod *F*. The block *B* is then made and ground true with the hole, which is tapped any fine pitch, from 24 to 40, as it is only for adjusting. The block has about $\frac{1}{2}$ inch of thread for the screw, while the remainder is bored out to receive the spring *H*. The bottom of the block must have a nice even bearing where it is in contact with the main block, also in the holes, and must work very nicely and without the least

shake. The plate *I* is a piece of tool steel, hardened and ground, and lapped to a nice straight edge on line *J*. The corresponding line or face against which the type rests is also lapped. The plate *I* is beveled off to a knife-edge and must fit nicely along the main block, the type when in place just high enough to allow it to pass over. The block *D* is fitted and pinned to the rod *F*, which is also a nice fit in the holes, and on the bearing face represented by line *K*, and is pushed forward by spring *L* against the type to hold it in place while the measures are being taken. The micrometer barrel was sawed from a half-inch micrometer, turned

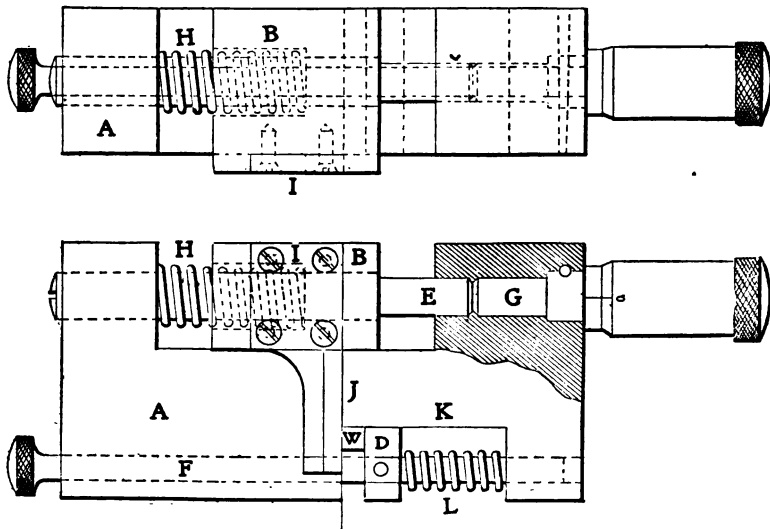


FIG. 75. — Gage for Type Faces.

to fit the block and pinned with a small taper pin. The screw *E* should be a tight fit in the block *B*, so that when it is once set there will be no liability of its turning. The screw should be threaded about $\frac{3}{4}$ inch to allow for adjusting the block *B*, which, when the micrometer screw is at 0 or zero, is brought so that it is exactly on the line *J*, and should not be moved unless in case of wear on the ends of the screws, as they are always in contact. Now let *W* represent a type in place ready to be measured. The micrometer screw is turned to the right, followed by the block *B*, until the knife-edge on *I* is at a point where the operator wishes to take his reading, which is done with the aid of a very strong glass.

A DEVICE FOR TESTING SQUARES

Another testing device which we noticed in a machine shop attracted our attention, and this is shown at Figs. 76 and 77.

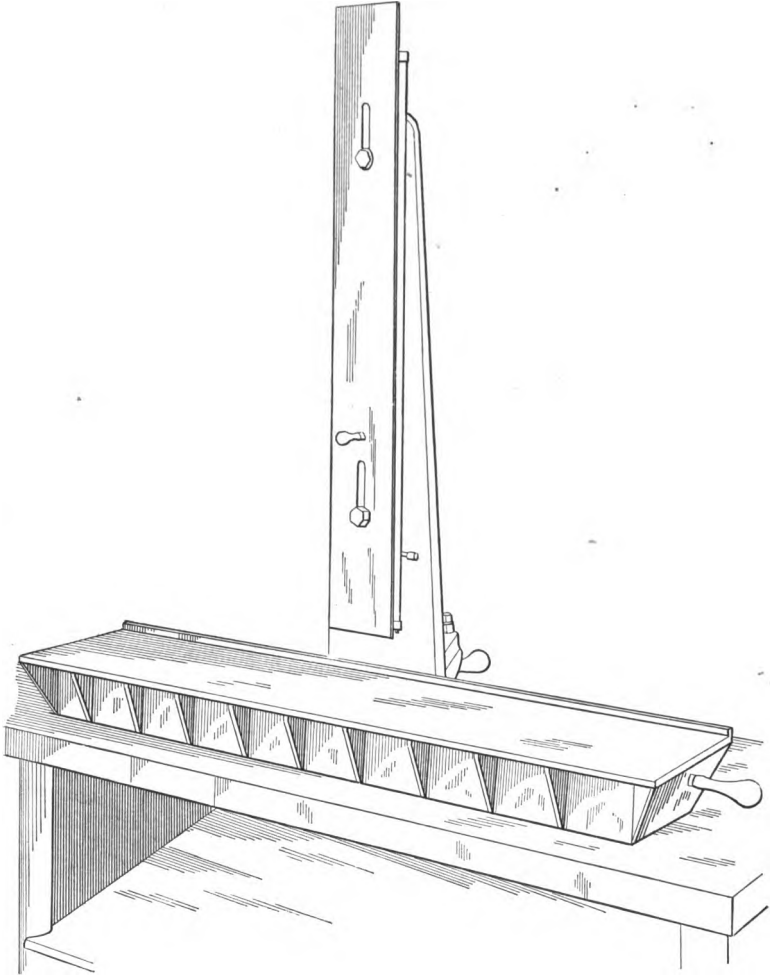


FIG. 76. — Square Testing Device.

The system of inspection in these shops is very rigid. Every piece is inspected as the different operations on it are completed upon it, and, of course, in doing this squares are used where necessary. There were constant complaints of the work not

coming square from the milling machines and the planers, and in very many cases where the inspectors declared a piece to be "out of square," and it was returned to the workman, he was able to show that by the square he had used — and which had been supplied to him from the tool-room — the piece was square. An investigation disclosed the fact that a piece might really be right by one square and a little off by another, and the trouble was thus traced to the squares themselves, although these had come from the same establishment and were believed, and for the same matter are still believed, to be the best and most accurate squares that are to be purchased anywhere. So the device Figs. 76 and 77 was made to test squares and to enable

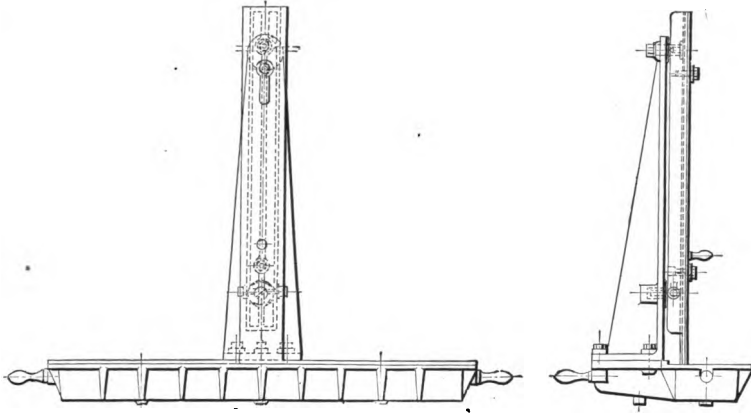


FIG. 77. — Square Testing Device.

them to be corrected when found slightly out. The surface plate which forms the plate of the device was carefully fitted by scraping to an original plate, and at the back of this it attached a standard which supports a straight-edge that has its sides as nearly straight and parallel with each other as it was possible to make them. This is adjustable vertically through a small distance, so that the lower end of it can be brought close to the stock of a square placed upon the surface plate when testing the inside edge, or close to the surface plate when testing the outside side of a square blade. At each end of the straight-edge, but just back of it, a long narrow mirror is placed. These mirrors swivel on pivots at top and bottom, so that the light which strikes them can be reflected to pass through the opening between a

square blade and the edge of the straight-edge, if there is any such opening; and when the straight-edge has been adjusted by means of knurled head screws, provided for that purpose, so that one edge of it exactly shuts out the light between itself and the square blade, the square is swung around to bring the same edge of the blade against the opposite edge of the straight-edge. This of course shows double the error that actually exists, and the square is then lapped until it will stand this test. It is now found that when an inspector declares a piece to be out of square, it will be found to be out also by the square the workmen used; in other words, the squares now agree with each other. It is, of course, a very refined test, and the device is beautifully made and finished. A drawing of the device is shown at Fig. 77, which, however, does not show the mirrors, one of which is seen in the engraving, Fig. 76. Perhaps they were added to strengthen the light after the device was made. In adjusting the straight-edge to agree with a square being tested, it swivels upon the pivot seen near the top of the standard in the drawing, and the adjusting screws are graduated to read to .001 millimeter per foot of length, and this, of course, enables errors to be known in definite terms of magnitude.

MICROMETER HEADS FOR SPECIAL GAGES

Considerable use is now being made of micrometer heads on special gages of various kinds, and as the advantages of these applications become more widely known, the use of these heads will undoubtedly increase. Their convenience of application to gages of various sorts, and the fact that they enable the variation from the exact size to be read in thousandths, render them superior in many cases to limit gages of the usual kind, and they are moreover applicable to a great variety of uses to which the usual fixed type gages would hardly be applied at all. Such gages are comparatively cheap, as the heads supply much of the really accurate work ready made, and they cost but little.

At the beginning, and in many cases still, these heads were obtained by cutting off the yoke of a complete micrometer caliper, but they are now being supplied by various makers without the yoke. Fig. 78 shows one of these heads as made by J. T. Slocomb & Co., of Providence, R. I., which does not differ from

the head of a complete caliper, except that it has turned and flanged seat for insertion in an eye of the special gage to which it is to be applied — the attachment of the head to the body of the gage being by soft solder.

Fig. 79 shows a cross-section of the head and illustrates a feature of the Slocomb head which renders it especially applicable to this use, namely, the provision for adjusting for wear in order to preserve the zero, which, it will be seen, is in the head itself.



FIG. 78. — Micrometer Head.

The main nut *a* is threaded into the barrel by a screw having thirty-two threads per inch, and as the measuring screw has forty threads per inch it will be seen that by turning the nut in the barrel the screw is adjusted along the barrel by the differential action of the two threads — this action being such as to give a movement of .0062 per revolution. Another feature of this head is the supplementary nut *b*, which is fitted with a row of V-shaped teeth on the end which faces the main nut *a*, these teeth engaging corresponding teeth in the main nut. By first

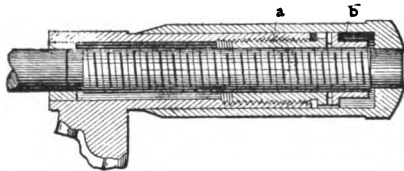


FIG. 79. — Micrometer Head.

withdrawing the screw and then turning nut *b* one or more teeth, any looseness in the threads due to wear may be taken up. Still another feature is the insertion of a light spring between nuts *a* and *b*, the object of which is to put a slight friction on the screw and thus prevent its accidental displacement.

Fig. 80 shows an instrument which is used in rebabbiting or otherwise re-establishing the journals of a lathe headstock. The micrometer head is carried by a ring which is so jointed to the stock of the tool as to turn upon it, and thus permit readings to be taken vertically or horizontally. One end of the babbitting

or testing mandrel is shown in position, the live spindle of the lathe being supposed to be removed. It is obvious that with a

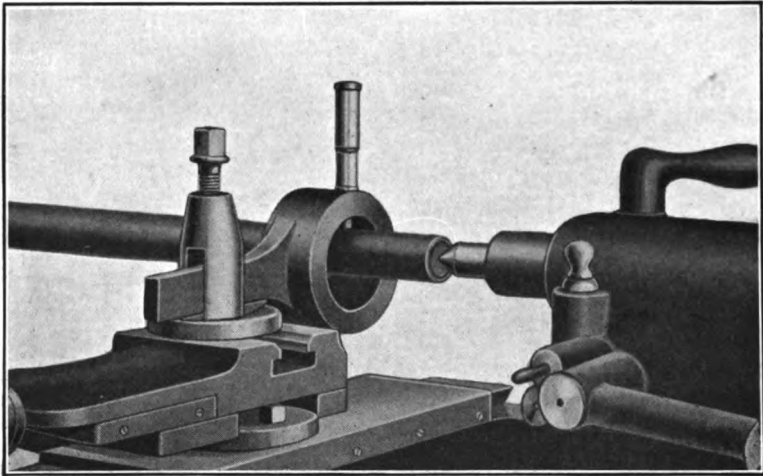


FIG. 80. — Testing Parallelism of Lathe Centers.

suitable support at the headstock end of the mandrel, it may by these means be adjusted to exact parallelism with the V's of the lathe.

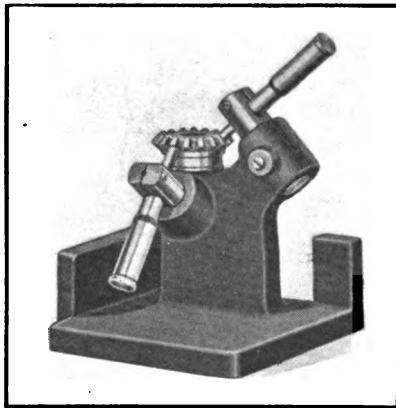


FIG. 81. — Gaging Bevel Gear Faces.

Fig. 81 shows a gage for determining the proper location of the bevel faces of bevel gears in relation to the hub face. This test is in reality applied to the blanks before the teeth are cut,

but by an oversight the photograph was taken with a completed gear in the gage.

Fig. 82 shows a tool of obvious utility in determining the degree of truth in a planer table. Other obvious uses for it are in boring mill and drill press tables and to lathe face-plates.

Fig. 83 shows a fixture for determining the correct diameter of the ball race in the crank shaft gear, back of the teeth, and under-cut so that the direct application of fixed gages is impossible. The gear is mounted on the spindle carried in the

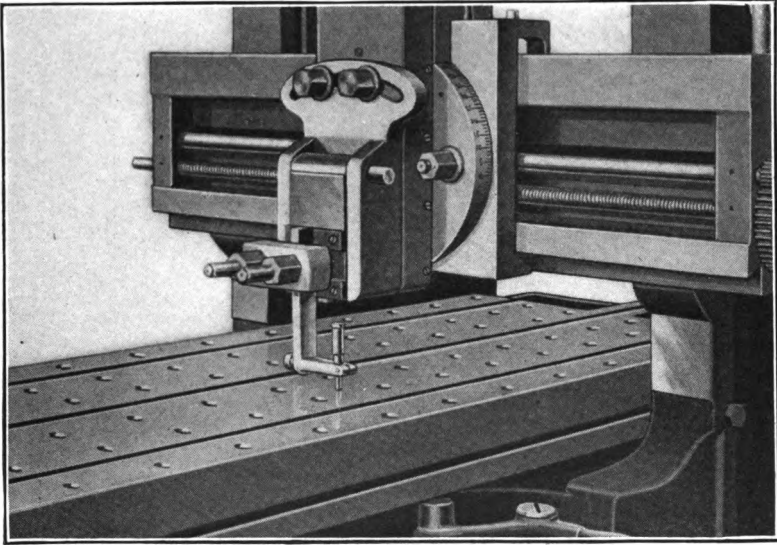
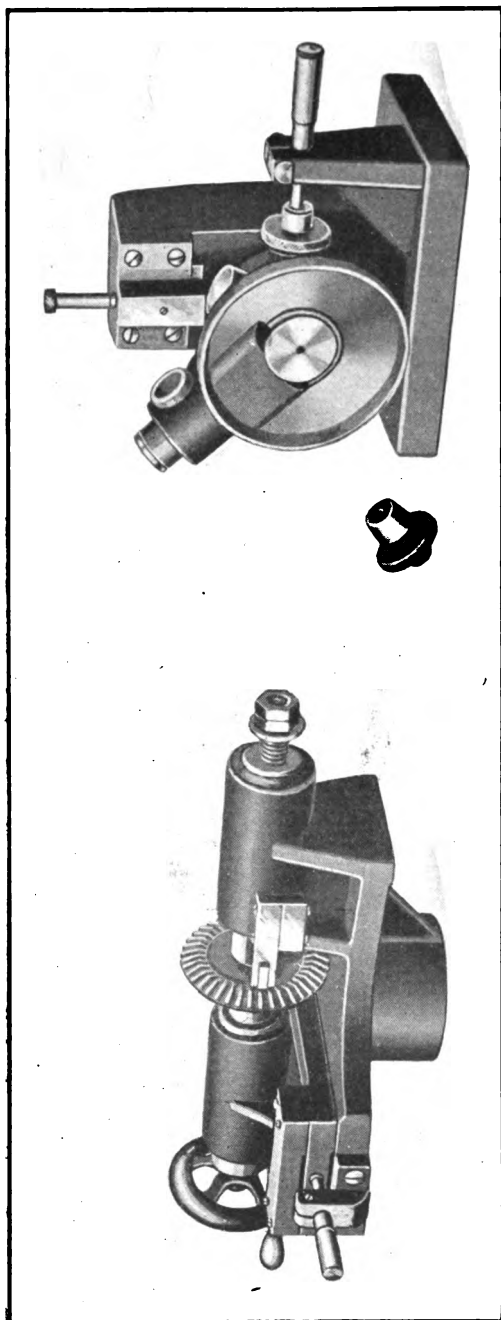


FIG. 82. — Testing Truth of Planer Table.

left-hand head of the fixture, and is carried longitudinally in the spindle bearing against an adjustable stop, which when once established is permanent. The abutment gage for the ball race is in front of the gear, and the spindle bearing has a transverse sliding movement, permitting the ball race to be brought into contact with the stop gage, when the micrometer may be read — the adjustment being preferably such that the reading when the work is exactly right is zero. It will be noticed that in this case, as in the others, the micrometer not only tells if the work is right, but if wrong it tells by how much, and furthermore, the limits between which the work is done may be determined after



FIGS. 83 and 84. — Special Micrometer Gages.

the gage is made and increased or diminished, if found advisable, instead of being — as with fixed gages — determined, and perhaps unwisely, before the gage is made.

Fig. 84 shows a gage for measuring the taper seats of a crank bracket in which the taper ends of the frame tubes are inserted. Certain diameters of these seats are required to be at proper distances from the axis of the bracket, and the accuracy of this is determined by the insertion of a taper plug — seen separate at the left — and then taking a reading with the micrometer.

SECTION III

LATHE, PLANER, SURFACE, AND UNIVERSAL GAGES AND INDICATORS; THEIR CONSTRUCTION AND USE.

SIMPLE AND INEXPENSIVE LATHE INDICATORS

AFTER being neglected for a number of years, it is well that at last the value and economy in the use of indicators in the tool, jobbing and manufacturing shops are becoming recognized and appreciated. A knowledge on the part of the mechanic of the uses and adaptability of the various designs of these handy and accurate tools will enable him to turn out more and better work with less effort and worry on his part than he possibly imagines. Their use guarantees the accurate location and running of the work in hand, and insures against error through neglect in having the fundamental placing correct. There is no guesswork where indicators are used.

A very simple and comparatively inexpensive lathe indicator can be constructed on lines similar to the one shown in Fig. 85. It is simply a rod centered to fit the lathe centers, or one lathe center and the work, as the case may be, and a needle or a surface gage. It can be used in a variety of ways. For instance, to chuck a piece of work to be bored on the carriage place one end against the center punch mark which locates the hole, and the other on the live centers; if the needle does not travel parallel to the face-plate the work is not chucked true. It may be necessary to turn the face-plate and needle together if the face-plate is not true. Of course this will locate only one point of the work, and care must be taken to chuck the piece so that the other end of the hole will come where it is wanted.

By having suitable centers in the ends of the rod, it can be used to set the tailstock center in line. The method is the same. Sometimes it can also be used to advantage in chucking work on the face-plate, as it is easier to rotate the light indicator than

to pull a heavy face-plate round. This is especially true when the work is liable to upset your calculations by sliding off on the ways. For everything except the last case the rod should be short in order to magnify the error as much as possible. The live center should also be true.

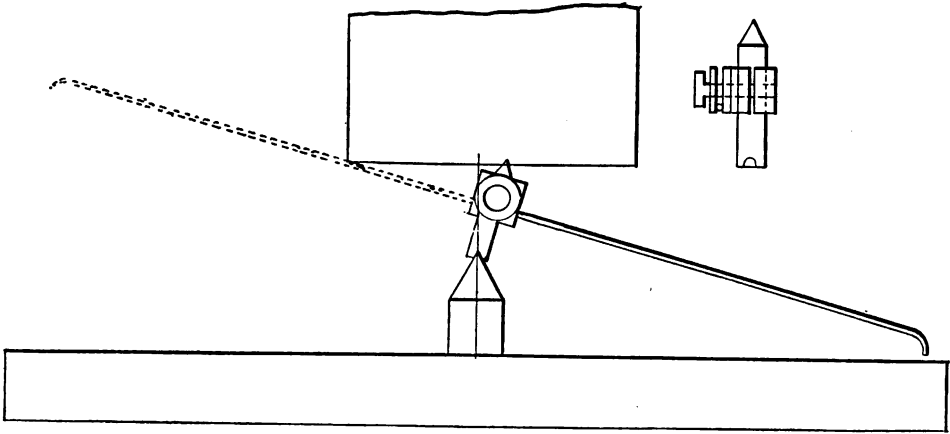


FIG. 85. — Simple Lathe Indicator.

A UNIVERSAL LATHE INDICATOR

Figs. 86 and 87 illustrate a universal indicator of novel and ingenious construction. It consists of a machine steel holder *A*, $\frac{1}{2} \times 1$ inch, carrying on its head a graduated arc *B* and pointer *C*, both held in position by a knurled thumb-screw (not shown),

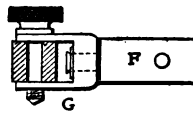


FIG. 86. — Universal Indicator.

which binds the arc to the holder, but allows the pointer to play over the face of the arc.

To the side of *A* is firmly bound a stiff spring *D*, which in turn carries near its upper edge a boss or hollow sleeve *E*, holding a sliding pin, which works against the short arm of the pointer at *a*. This is for testing the face of the work held in the chuck or on a mandrel, or to find whether a piece on the center is out of round.



To the outer end of *D* is secured, by means of a knurled thumb-screw, the slotted pin *F*, carrying the yoke *G*, both together making a universal joint which carries the long, light pointer or needle for testing by center punch mark in the usual way.

By binding the needle in the yoke through means of the thumb-screws to prevent side motion, and adjusting the spring and joint by means of thumb-screws *b* and *c*, the needle is brought into position to test the truth of the hole.

All parts are detachable when not needed by simply removing their respective thumb-screws.

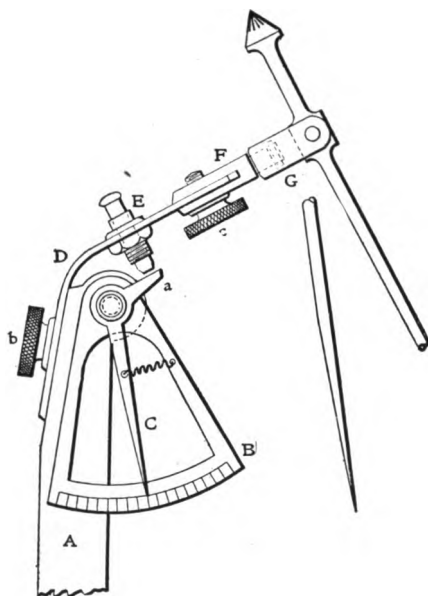
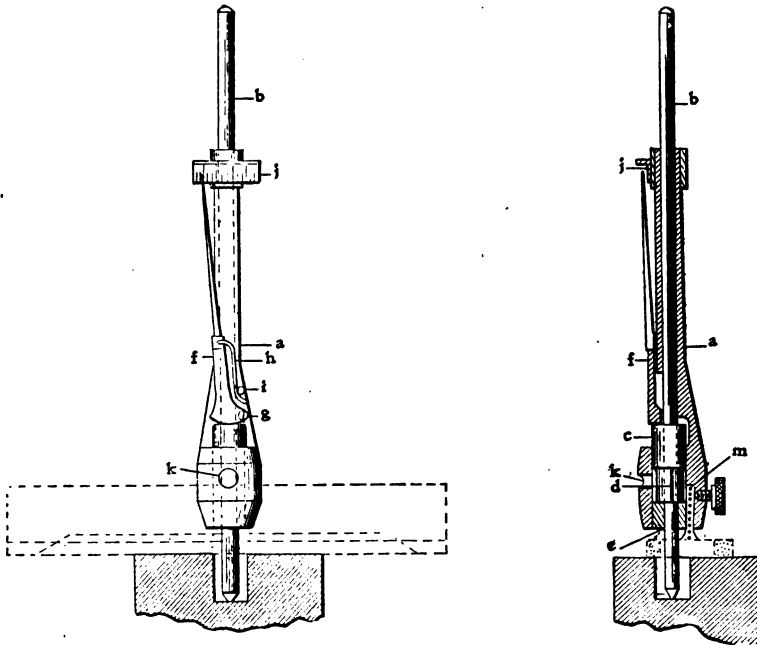


FIG. 87. — Universal Indicator.

A DECIMALLY GRADUATED UNIVERSAL INDICATOR

Figs. 88, 89 and 90 show a front elevation and a vertical transverse section of an extremely complete and accurate universal indicator as attached to an angular steel base, and in use as a depth gage. The construction is as follows: A tubular body or shell *a*, through the center of which a rod *b* passes and is held in any desired position by the friction collar *c*, which is slotted at *d*. The friction collar *c* is fitted free in the enlarged bore of *a* with a

limited amount of longitudinal movement, and is held in the shell by the plug *e*, which is fitted tight. The shell is cut away to give a flat surface on one side for the placing of the indicator needle and spring. Indicator needle *f* is pivoted to the shell by a small screw at *g*, the heel of the needle bearing on the friction collar *c* by the pressure of the feather spring *b*. The spring is "sweat" into a small slot in the needle, and rests against the pin *i*. The needle point is shown about in its normal position,



FIGS. 88 and 89. — Decimally Graduated Indicator.

with the friction collar resting on the plug *e*. An upward movement of the rod *b* and friction collar *c* would move the needle point to the right. Scale *j* is graduated to read approximately to thousandths of an inch, within a range of twenty-five thousandths.

The tools are applied to the ordinary surface gage as illustrated in Fig. 90. A taper hole in the body or shell at *k* provides means of attaching it to the wire rod of the surface gage. The engravings show the operation of taking the deflections from end to end of the cross rail of a planer from the platen.

The slot at *m*, Fig. 89, may be used in connection with a steel rule or the blade of a square. The tool-maker will find many other uses for the instrument than those herein shown, such as testing a lathe center, showing the amount of wear of tool slides, leveling work in the milling machine or planer, inspection of finished work, etc. The indicator may be carried in the vest

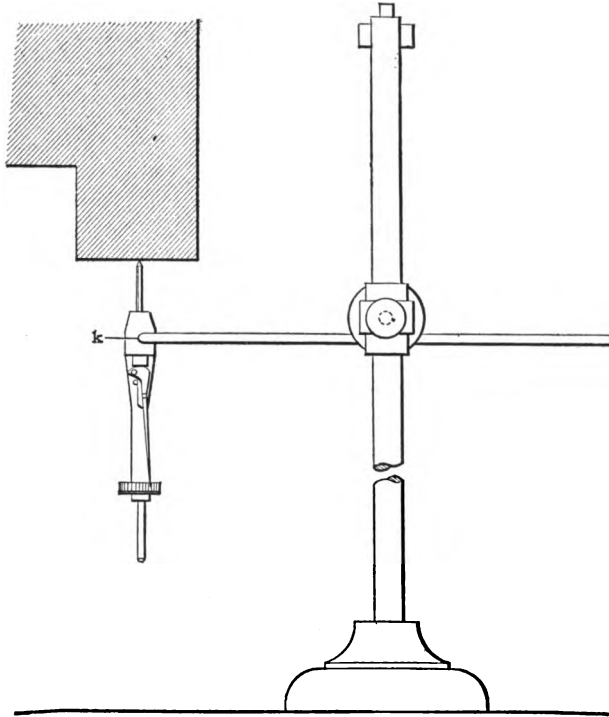
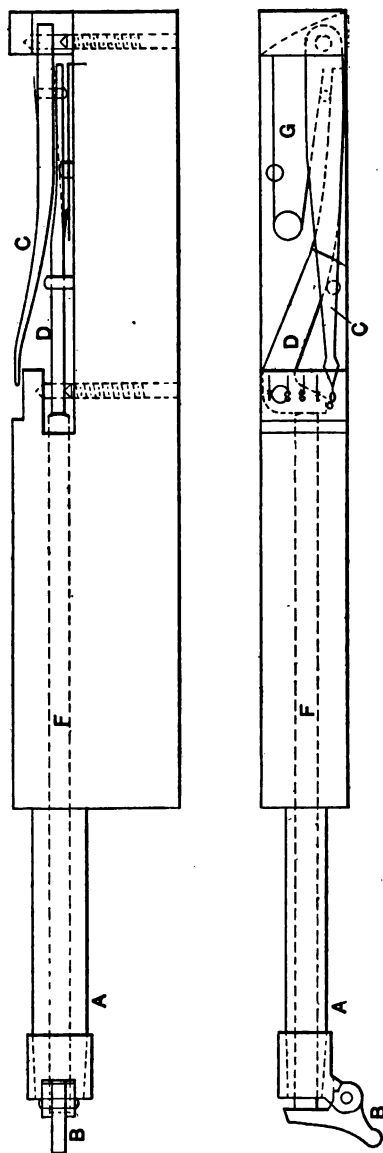


FIG. 90. — Decimally Graduated Indicator.

pocket, its weight, without the rod, being three quarters of an ounce. The inventor of this handy tool is Charles E. Hauer, a tool-maker, and foreman in the factory of the Westinghouse Electric & Manufacturing Company.

A LATHE AND PLANER INDICATOR

The following description of a lathe and planer indicator refers to the one illustrated in Figs. 91 and 92. It is unexcelled



FIGS. 91 and 92.—Lathe and Planer Indicator.

for the work for which it was designed. It is graduated to indicate thousandths, and by multiplication of the needle movement by compound levers, the slightest error is easily detected. The projecting barrel *A* allows the feeler *B* to be used in a very contracted space and in deep holes. The end of the barrel is tapered and the holder for the feeler *B* fits over it. The position of the feeler relative to the barrel may be changed by simply twisting it round. The movement of the feeler is transmitted through *F* to the lever *D*, which is restrained by the spring *G*,

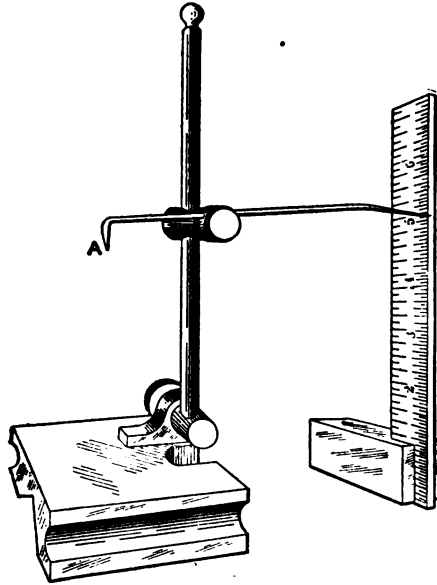


FIG. 93. — Adjusting Surface Gage.

and which engages the pointer *C*. The body of the holder fits in an ordinary tool-post. The cut is nearly a full size reproduction of the indicator.

TO ADJUST THE NEEDLE OF A SURFACE GAGE

To set the gage, Fig. 93, from the table, get somewhere within one quarter inch of the mark on the square. With the thumb and forefinger on the crook *A*, turn the needle until it reaches the point desired. By turning the needle it will travel in the path indicated by the dotted lines shown, on account of the bend near the point.

A TOOL-MAKER'S SCRATCH BLOCK

A, Fig. 94, is the body or block which is bored to receive the shaft *B*, to which is keyed the worm gear *C*, this being held against the shoulder by the sleeve *J*, which screws in to the block far enough to make a bearing on the outer shoulder and still let the worm gear and shaft work easily without end thrust. The shaft *B* also shoulders in the block at *M*, and when the nut *I* is tightened on the sleeve *J*, the gear and shaft must be free to turn with-

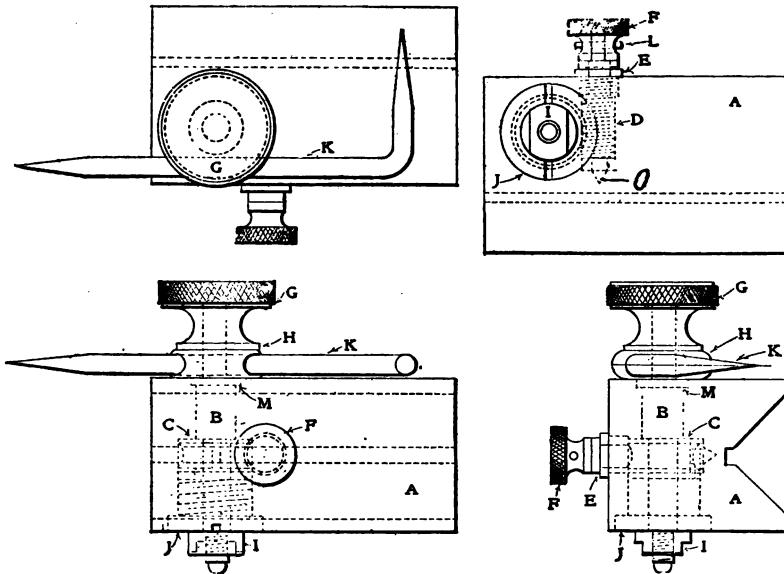


FIG. 94. — Tool-Maker's Scratch Block.

out end play. *H* is a washer, or rather two half washers, drilled when together to receive the pointer *K*, the thumb-nut *G* binding the pointer, at the same time bringing the back of the washer against the shoulder on *B*, which is just flush with the face of the block, but not allowing the washer to bind on the block.

The shaft, gear, washer, pointer, and all now being free to turn, after being set very near and before the pointer is tightened, may be worked as desired by the worm *D*, the end of which fits into the conical bearing *O*, and is held in position by the sleeve *E* which screws into the block and against the shoulder on *D*, so that it will turn easily without any end play. The knurled head

F is pinned by the taper cross-pin *L* to the worm. The worm wheel was made with a $\frac{1}{4}$ -inch 24-thread master tap in the lathe. Any one wishing to make a scratch block will find this to be a very good one.

A CHEAP SURFACE GAGE

The principal part of the gage Fig. 95 is made from an old pair of calipers. *A* is a small base, with a slot milled down the center for one leg of the caliper, which is then held in by pins. *B* is a reinforcement on the other leg so as to make it strong enough to hold the scriber *C*. The base is cut away at *D* to admit the stud on the caliper. With the split nut a fine adjustment is obtained as well as a quick one.

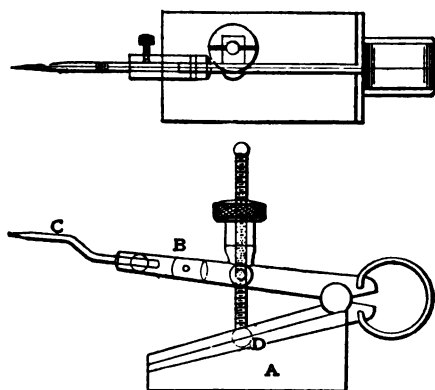


FIG. 95. — Cheap Surface Gage.

A SURFACE GAGE AND INDICATOR

Fig. 96 show a surface gage and indicator with a number of features not usually found and embodied in such instruments. It will be noticed in the first place that the post or spindle has a taper fit in the base, the latter therefore being removable, and as there is a good center in each end of the spindle, the instrument may be used upon the lathe centers, as well as upon planers, shapers, milling machines and elsewhere. The scriber used, it will be noticed, is shown in the sketch with a minute prick punch in the lower end of it. This punch is normally held up against a shoulder by a little helical spring, a tap with a light hammer bringing it down to make its mark when required. The scriber

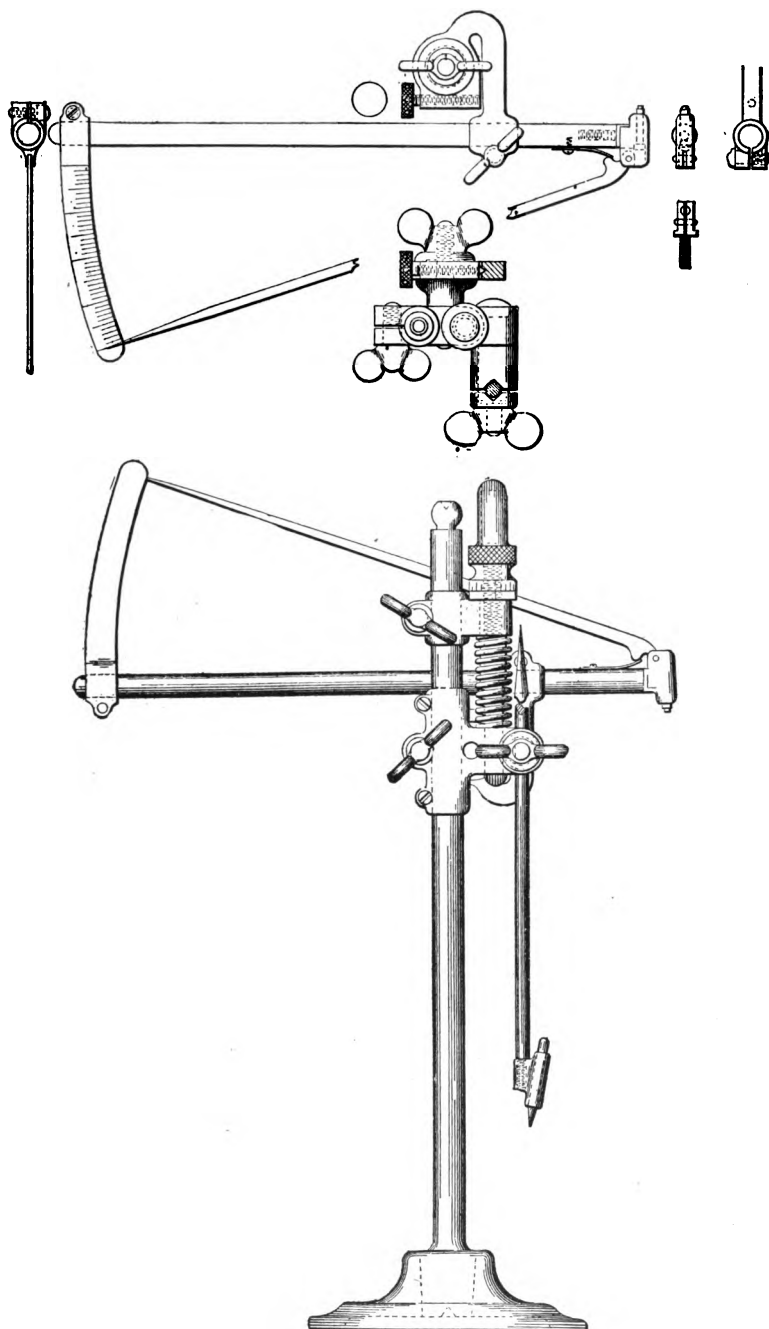


FIG. 96.—Surface Gage and Indicator.

may be usually set in such a direction as to bring the prick punch perpendicular to the surface with which it is at the time concerned. The scriber is of course reversed end for end when lining is to be done.

Upon the spindle are fitted the two split sleeves which may be clamped at any point by their respective screws. The upper of these may be called the fixed sleeve, and the lower the adjustable sleeve. The sleeves are normally held apart by the compression spring and drawn toward each other in opposition to the spring by a long stud so fixed, screw attached to the lower sleeve and a milled-head nut fitted to it, which bears upon a shoulder on the upper side of the upper sleeve. The thread of the screw is $\frac{1}{40}$ to the inch, and the periphery of the nut having 25 divisions, the reading is in thousandths of an inch. The nut is extended upward into a closed thimble which entirely covers the end of the screw. The upper sleeve being clamped securely, the screw of the lower sleeve may be loosened just enough to permit the lower sleeve and its appurtenances to be moved, and the movement is indicated by the reading of the nut. The adjustable sleeve carries the scriber in front, which may be clamped in any position, as shown. At the back it carries a mounting for the surface indicator, which is used for inspecting and indicating the minute variations of plane surfaces. The rod of the indicator may be slid edgewise in its mounting as required, and it may be reversed as shown in the upper figure. The indicator consists of a little vertically moving hardened steel-plunger, the inner end of which bears against the short end of the spring-actuated lever, the long end of which is a finger which traverses the graduated quadrant, giving readings to the thousandths of an inch. The mounting which carries this indicator is bent upon itself so as to form a long slit or opening and to permit the piece to be sprung apart by the pressure of the horizontal milled head-screw seen in the upper figure. This screw is used for giving minute movement of the indicator when required to bring the reading of the figure accurately to one of the graduation marks, or when the indicator is used in connection with the scriber, to bring them both to co-incident graduation marks. The applications of this instrument will suggest themselves to those who are familiar with the cruder instruments of the same class, and which are used so extensively.

INDICATORS AS APPLIED TO MILLING MACHINES

While the usefulness of the graduated multiplying indicator as applied to the lathe, planer and testing work is pretty generally understood, there are many other operations in all departments of metal manufacture, where by its use work can be both facilitated and improved. Having lately experimented with very satisfactory results for the purpose of determining its actual value in a regular line of machine-tool milling, we will try and describe a few operations where it was used to advantage.

In Fig. 97 a freshly ground cutter is shown mounted on a lathe mandrel (previously tested) in a pair of Pratt & Whitney centers having an indicator attached, to determine if (when re-

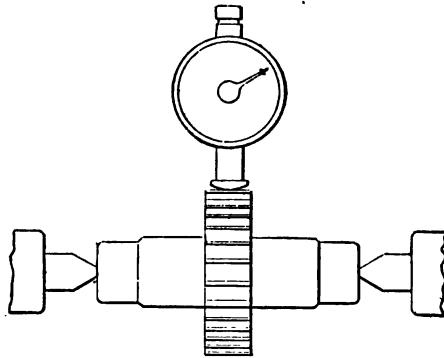


FIG. 97. — Testing Cutter with Indicator.

volving) all the teeth are “even” or concentric. This is especially useful when applied to machine-relieved cutters. Fig. 98 shows a rig for holding the indicator while truing a cutter when both cutter and arbor are in place on the machine.

Arbors are ground from .003 to .005 inch smaller than the sizes of standard holes in cutters, to permit the shifting of the cutters when truing. Indicators having flat shanks or stems are most convenient when they are used occasionally, or on different machines, as they then can be readily clamped to fixtures, work or table, and in many positions. When they can be suspended from the overhanging arm, as in Fig. 99, or column, those with round shanks or stems are best.

Fig. 100 shows how single or double-ended facing and boring cutters in boring-bar are tested, both for diameter of hole to be

bored and for truth, displacing the old cut-and-dried method by one absolutely certain.

Anticipating objections which may be made to having arbors smaller than holes in cutters on account of shifting, we will say that with a 4-pitch gear cutter having a hole .01 inch larger than arbor, we milled 50 inches of steel $\frac{1}{2}$ inch deep at a speed of 37 feet per minute and .008 inch table feed per revolution; and

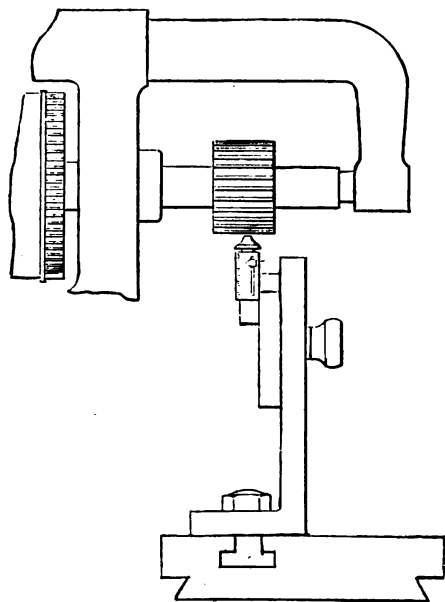


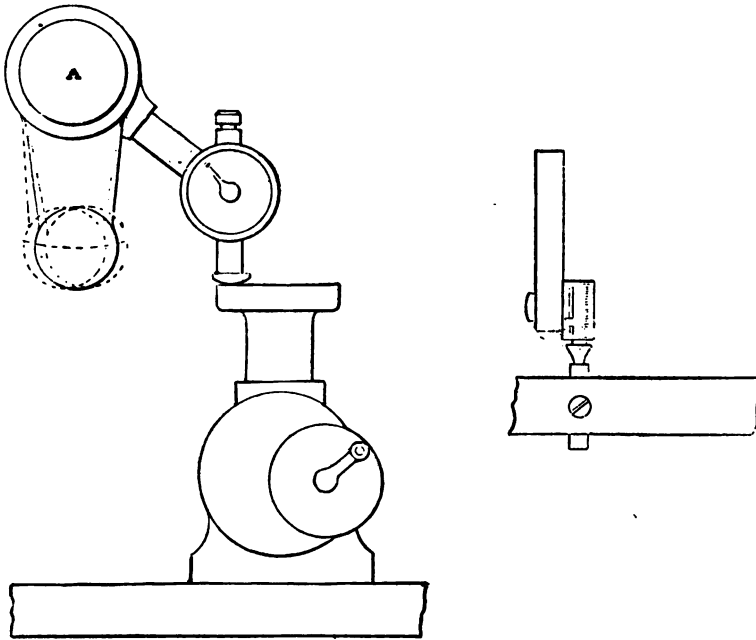
FIG. 98. — Truing Cutter.

again, 15 inches, $\frac{1}{2}$ inch deep, at a speed of 41 feet and .150 inch feed per revolution without shifting the cutter; also the arbor was not splined. This forces the conclusion that when arbor collars are properly proportioned and in good condition, they will not slip unless abused or overloaded; also that keyways, for the most part, are unnecessary. Cutters properly ground, running true, with every tooth doing its proper share of work, last longer, do better work, and can be crowded harder than when any of these essentials are missing. We neglected to state that in truing we established a limit of error of .002 inch, though .001 inch is easily attainable.

A TEST INDICATOR

The drawings, Figs. 101 to 104, illustrate an indicator which we designed and made. The important feature of this tool is the dial, which though only $1\frac{1}{8}$ inches diameter, gives room to show errors highly magnified, the ratio being 350 to 1.

The graduations read in half thousandths, but quarter-thousandths or even smaller amounts can easily be estimated. The



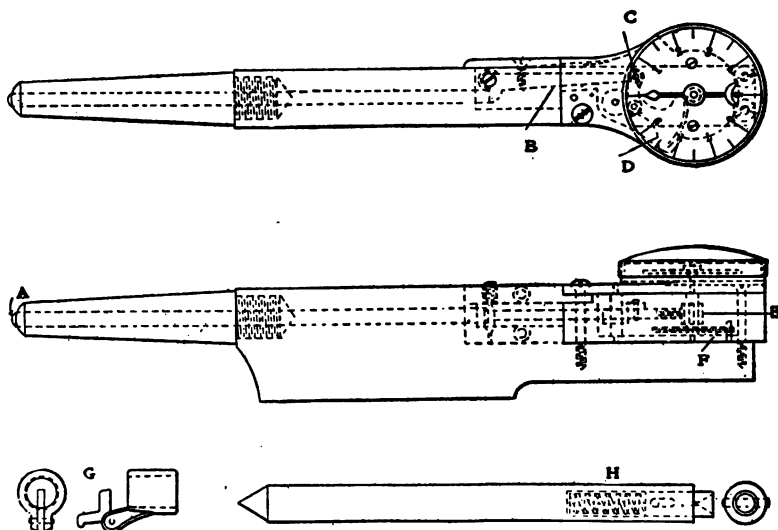
FIGS. 99 and 100. — Uses of Test Indicator.

limit is ten one-thousandths, or one turn of the pointer. When in use the plunger *A* touches the work and any imperfection will cause it to move the lever *B*, which through link *C* actuates the gear segment *D* and rotates the pinion *E* with the spindle carrying the pointer. The latter is returned to zero by a volute spring *F*.

The attachment *G* is used for inside work, or for testing any surface at right angles to the indicator. The tool *H* is used in testing centers in lathe work held on the face-plate or in the chuck.

All working parts are encased, and the dial is with a heavy watch crystal, which makes it dust proof. A watch crystal may seem out of place in a machinist's kit, but it is a good thing to have if for no other reason than that it silently demands the careful treatment such a tool deserves.

This indicator is not only adapted to lathe work, but is often found very useful when setting in the shaper or the planer, and especially in setting shaper vises perfectly true.



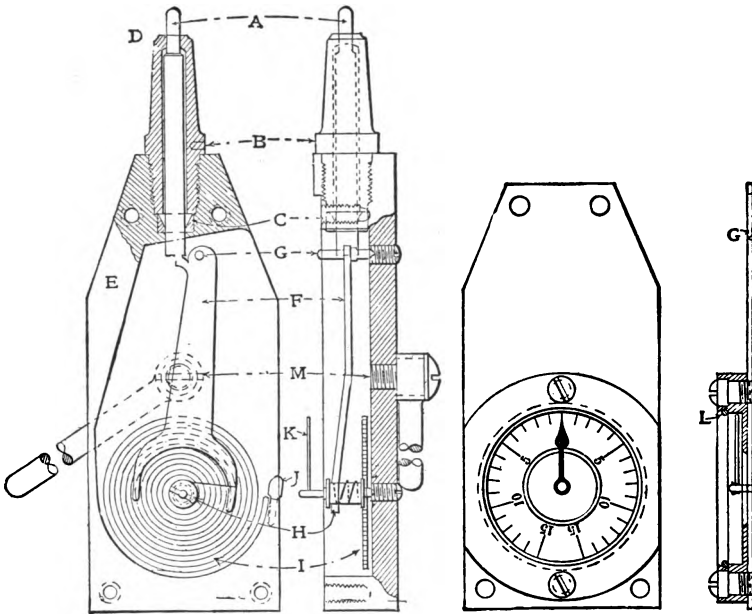
FIGS. 101, 102, 103 and 104. — Test Indicator.

A TEST INDICATOR AND HOLDER

Figs. 105 and 106 illustrate a test indicator which we found to be very useful. Fig. 105 shows the body of the instrument with the cover removed. The tool carries, as shown, a pointer *A* which is of tool steel, hardened, ground and lapped to fit sleeve *B* and bushing *C*, rod *A* being shouldered near *D* to prevent it falling out of the sleeve. Member *A* is of course the "feeler"; *C* is a hardened bushing which supports the inner end of *A*; it is beveled internally to leave only about $\frac{1}{32}$ -inch bearing and is forced in the tap hole in *E* by screwing sleeve *B* down on top of it. The pin *A* after passing through *B* and *C* passes through a clearance hole in *E*, where it engages with the forked lever *F* which works on a pivot carried between an adjusting screw in the body and a

conical seat at *G* in the cover (Fig. 106). A silk thread fastened to one of the arms at the forked end of the lever (the other arm being merely a stop for the lever) passes several times around drum *H*, thence through a hole in the lower end of the latter, which is countersunk at one side so that a knot to fasten the thread may be drawn into it.

At *I* is shown a hair spring which is driven on the drum shaft and held at *J* in a drilled hole in the body of the tool by a small



FIGS. 105 and 106. — Test Indicator and Holder.

knurled plug forced into the hole. The hair spring keeps an even tension on the thread by pulling on the drum from the opposite direction. On the upper end of the drum shaft is a watch hand *K* which is revolved by any movement of pin *A* and lever *F*.

Fig. 106 shows the cover and the dial with the watch hand at zero on the dial. The cover is a piece of sheet steel fastened to the indicator body with small machine screws and having a hole through it to act as the upper bearing for the drum shaft. The dial has a beveled edge as represented, and is fastened in place

by means of a ring and two small screws. A piece of photographic film with the emulsion washed off is cut out and laid on the shoulder just above the pointer and held in place by a round spring of piano wire in the beveled seat *L*, thus effectually keeping the dial free from dust.

In graduating the dial we fastened the disk in place on the cover of the indicator, then placed the indicator in a tool-holder, held it in the lathe tool-post and brought the end of *A* in contact with the face-plate of the lathe, first, however, scribing a zero line on the dial. Then we forced the pointer against the face-

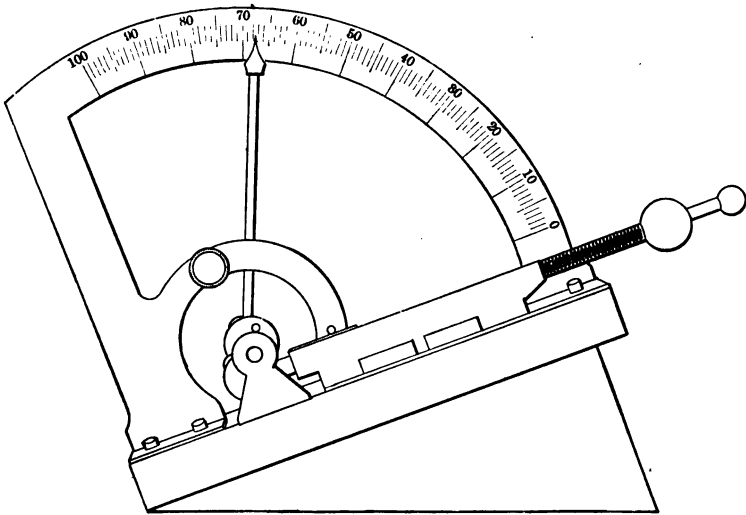


FIG. 107.—Inclinometer and Indicator.

plate till the indicating hand was at zero. Next, we slipped a piece of sheet metal .015 inch thick under *A* and scribed a line where indicated, and so on.

INCLINOMETER AND INDICATOR

The photograph, Fig. 107, shows a simple and useful tool which we have just made and which can be used as a level, as an indicator, and for getting the angle of an inclined surface. The tool is graduated at each side, one pointer serving for both sides, as the top part of the pointer, or hand, is double and the quadrant passes between the two points; thus it can be easily read from

either side. The pointer is fastened to a shaft, the ends of which are pointed; on the bottom is fastened a weight which always keeps the hand vertical, and when the tool is placed upon a surface to see if it is level or at an angle, the hand shows it at once, or rather after a second or so, for it vibrates a little. The test indicator which we have added to the base has at the end a hardening wheel; a coiled spring keeps the plunger away from the weight at the bottom of the pointer. When this indicator is used it is pushed against the work, and the rod, pushing against the weight, moves the hand in the direction of *O* on the quadrant, the weight of the tool holding it. A movement of .001

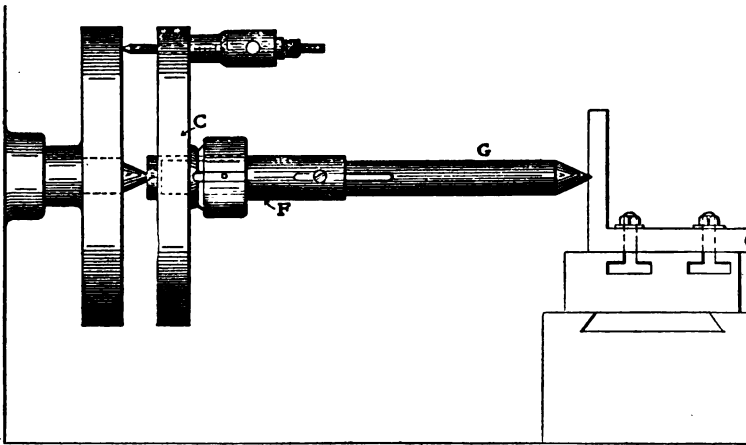


FIG. 108. — Lathe Indicator.

causes the hand to move from one line to the next. It will be observed in the photograph, that there are pins or stops which keep the hand from striking against the quadrant; also a screw to lock the hand so that the tool can be carried about.

A LATHE INDICATOR

The instrument shown in Figs. 108 and 109, recently patented by John C. Miller, Bloomfield, N. J., is to be used in connection with a lathe or a milling machine for setting the center of the work, or any center punch mark on the work, in line with the center of the spindle. The operation of the device is evident. The disk *C* has a split hub and a nut by which it is clamped anywhere on the sleeve *F*. The center in the closed

end of this sleeve is placed on the center of the machine spindle, and the center on the end of *G* is placed in the center of the piece of work to be located, the spring acting to press both centers with sufficient force to hold the instrument securely. Near the periphery of the disk is a micrometrically adjusted pointer, and by turning the instrument around the contact of this pointer with the face-plate will indicate in which direction the work requires to be moved to correct setting. Any desirable limit of precision may be observed in the micrometer, and the work may be set without the present difficulty.

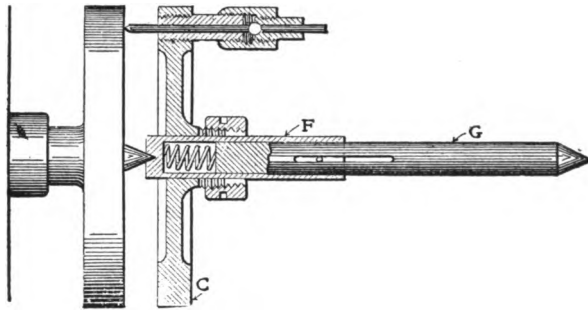


FIG. 109. — Lathe Indicator.

A TEST INDICATOR

As tool-makers are always interested in seeing something new, especially if it is a good tool to add to their collection in the tool chest, the following will be of interest:

The photograph, Fig. 110, shows a test indicator which is all right. As is plainly shown, it will go where any lathe, shaper or planer tool will go, or it can be used in the milling machine, as the whole mechanism is arranged within the stock.

We find it sensitive to 1-20000 part of an inch on smooth work revolving in the lathe. This seems rather fine, but this error can be easily detected by closely observing the pointer.

As will be noticed, the lever system is arranged sidewise, so as not to weaken the section where the tool-post screw clamps. The body is made of a piece of cold rolled steel with one end turned down as shown. The push-pin is of tool-steel, and presses against the main lever.

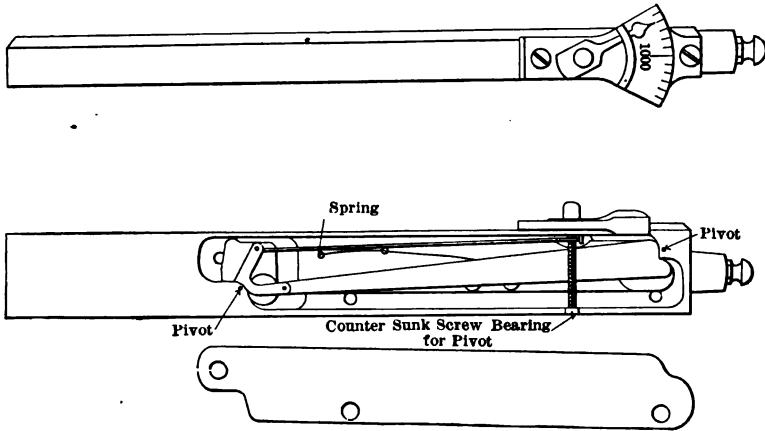


FIG. 110. — Test Indicator.

THE USE OF TEST INDICATORS FOR TESTING WORK

In Fig. 111 is shown a method for determining by the use of an indicator the variations in the diameter of numbers of round pieces, or at various points, longitudinally or circumferentially,

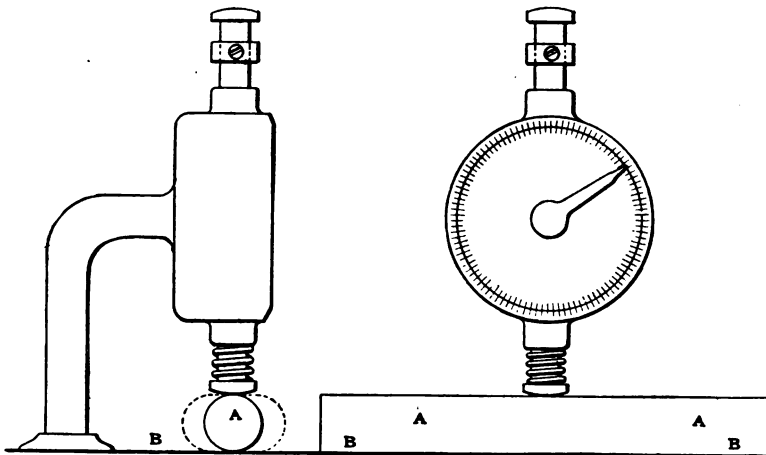


FIG. 111. — Testing Round Pieces.

of a single piece or between a number of pieces of unknown diameter and one of known diameter. An indicator is fixed upon a plane surface *B*, and the piece to be tested, *A*, is rolled back and forth between it, and by contact with the shoe of the indicator

spindle it causes the pointer to travel the graduated circle, pieces of larger or smaller diameter causing it to be traveled a greater or less distance, respectively. This rig is also useful for comparing two or more portions of a flat or square surface of a number of pieces. When testing a number of pieces — round — the small collar at the upper end of the spindle is adjusted vertically so as to allow the lowest part of the shoe to hang slightly lower than when *A* is in contact; otherwise it would be necessary to raise the spindle each time work was to be inserted. The chief advantages of this arrangement are its rapidity and also its reliability; so that different persons are more likely to get similar results than by using micrometers, the results from

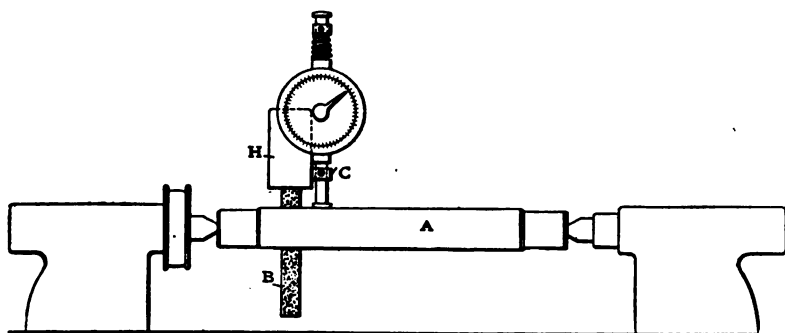


FIG. 112. — Setting a Grinding Machine.

which are governed by variations in instruments, body heat and personal temperament.

In Fig. 112 is shown a method of setting a grinding machine to grind straight or to a desired taper in thousandths of an inch for any portion of — or the entire length — work without stopping the machine. By depressing the indicator spindle until the shoe comes into contact with work *A*, variations in diameter, if any, are instantly shown. This can also be used to determine the diameter when a number of pieces are to be ground, and the operator can always instantly inform himself as to the amount of stock that is still to be removed; also, before beginning to grind, how much stock must necessarily be removed to make a piece round, if it should not run true, or, in shop language, to “see if it will true up.” *B* is the wheel, *H* the hood over the wheel to which the indicator is affixed, and *P* the swiveling plate carrying head and tail stocks.

In Fig. 113 we show a straightening press with centers, attached to which is an indicator *I* secured by an L-clamp *D*. Where this device was employed, as a great deal of work to be ground was turned on screw machines and centered afterwards, with an allowance of only .003 to .005 inch for grinding, and as the grinder operators often found it impossible to judge before beginning to grind whether pieces ran true enough to grind all around, it was necessary to have some means by which this point could be determined quickly. The center stocks supporting the blocks and bar can be moved independently, and the center stocks can, if desired, be moved to the right or the left end of the bar, so that

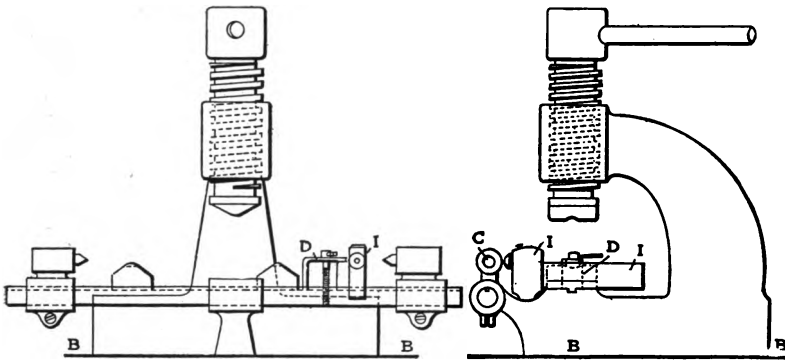


FIG. 113. — Straightening Press.

any portion of any piece can be tested. The addition of the indicator to the press does not decrease its efficiency as a straightening press but rather increases it.

THE R. R. UNIVERSAL TEST INDICATOR AND HEIGHT GAGE

The illustration, Fig. 114, shows the Roach & Ridlon tools, which consist of the indicator attached to the rod by a swiveling clamp; a plunger for aligning jig and die work; a small button to take the place of the ball on the indicator when the tool is used in the drill press aligning jig and die work, and the case-hardened tool-holder which can be used as a boring tool-holder when not in use in connection with the indicator. The tool is compact and neat in appearance. It is graduated to read to thousandths of an inch.

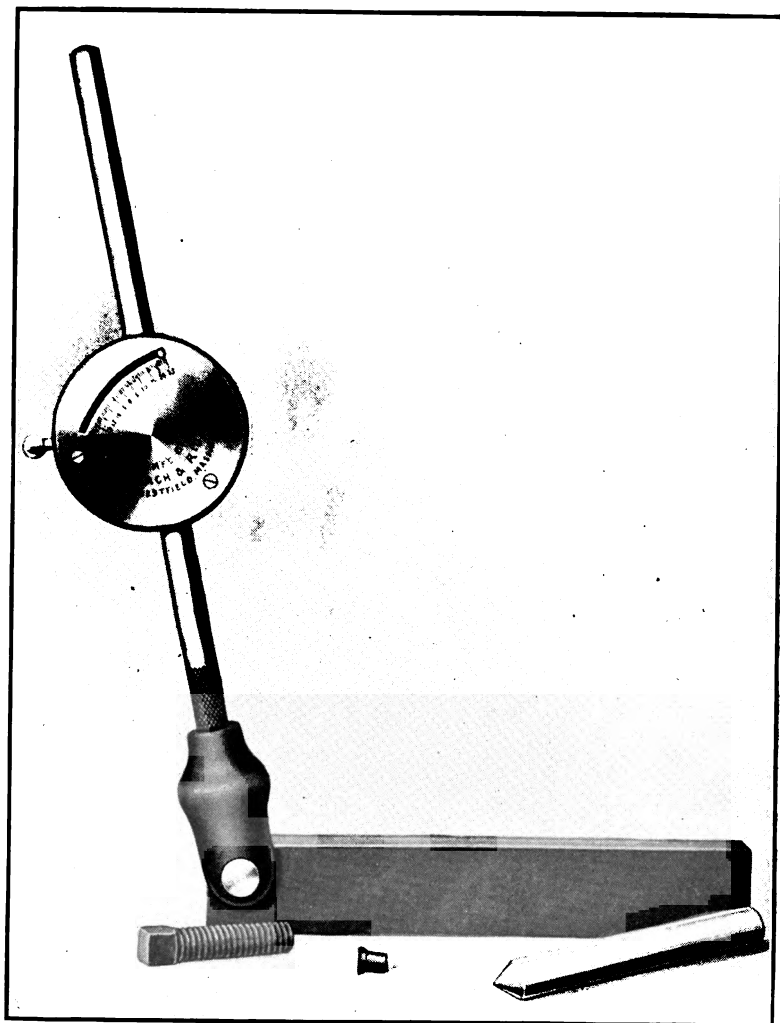


FIG. 114. — Universal Indicator.

SCALE AND VERNIER FOR FINE ADJUSTMENT OF THE MILLING MACHINE TABLE

Referring to the use of the scale and vernier of a vernier caliper for making accurate adjustments of the milling machine table, the Brown & Sharpe Manufacturing Company make a special scale and vernier which they supply for this purpose, and which we illustrate herewith in Fig. 115. The scale is 24 inches long, and the vernier reads to thousandths. The scale is mounted by screws having T-shaped nuts to enter the trip-dog slot of the table, and the vernier is attached to the front of the saddle of the machine. In the illustration *a* shows the

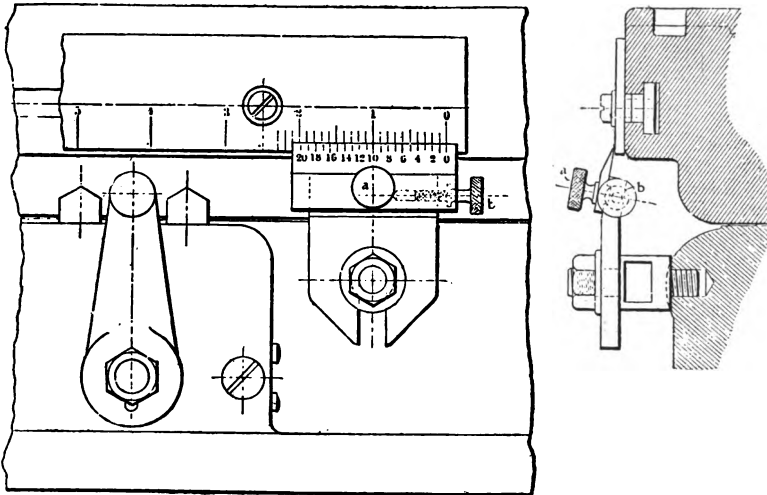


FIG. 115.— Vernier Adjustment.

clamp screw for the vernier and *b* an adjusting screw by which the zero is adjusted.

In the engraving the finer divisions of the scale are omitted.

UNIVERSAL SURFACE GAGE WITH MICROMETER ADJUSTMENT

The general principle of this gage can be seen at a glance in Fig. 116: There is a micrometer adjustment for the needle, and in tilting the spindle, as shown in the upper sketch, the level comes in play as before, and the reading in thousandths in a vertical line can be taken with precision; or, if desired, the needle can be reversed by swinging half round, bringing the thumb-screw at the bottom, when the level comes in play again the same as before.

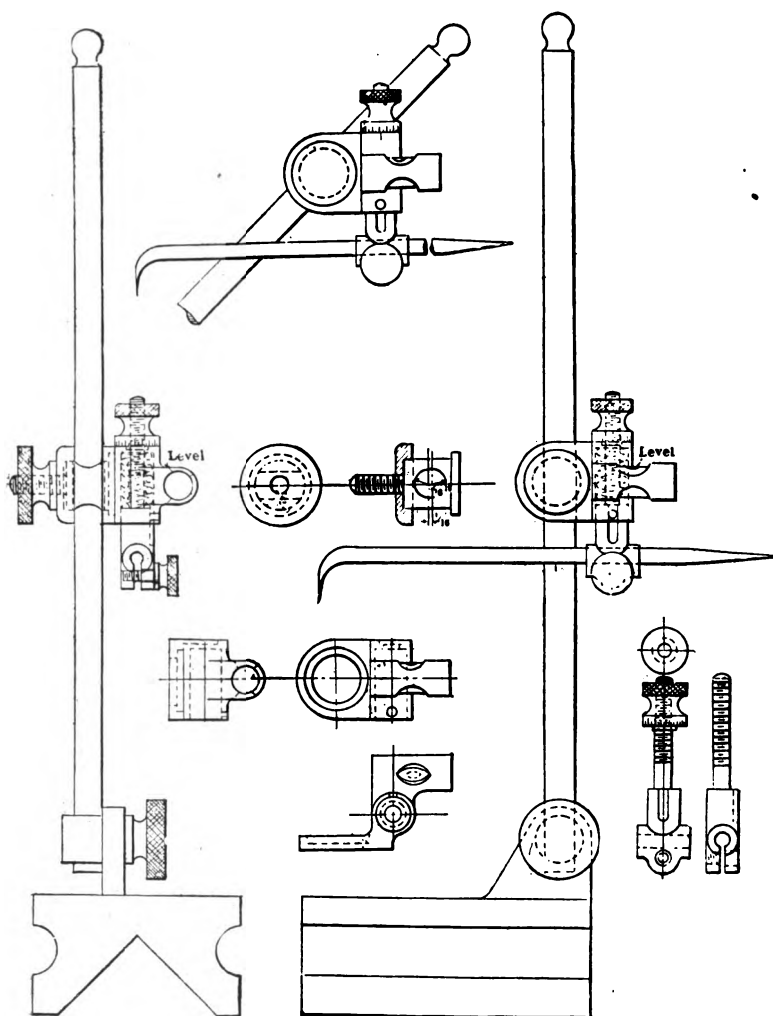


FIG. 116. — Surface Gage with Micrometer Attachment.

SECTION IV

THREAD, WORM, GEAR TOOTH, DEPTH AND MISCELLANEOUS TEST TOOLS, THEIR CONSTRUCTION, USE AND ADAPTATION.

A WORM AND SPIRAL GEAR TOOTH GAGE

It is apparent from the great interest manifested in all articles published relating to screw-cutting and forms of teeth in spiral and worm gearing, that there is a large amount of this class of work being done throughout the country. Those interested in spiral and worm gearing may make use of the thread tool gage shown here, with which spiral and worm gears can be figured out near enough for all practical purposes.

From the accompanying illustrations, Figs. 117 and 118, it will be seen that there are two scales used in this gage; the upper one is the circular pitch scale *A*, graduated on the top edge only, the reading being taken from point *d* directly above the center pin. The lower graduation is read by setting the point *f* on the thread gage to correspond with the width of the thread tool at its end, this being taken from a table of tooth parts, such as one published by the Brown & Sharpe Company.

Note that *C* is adjustable independent of the main slide, but is set in correct relation to it, and, as shown in Fig. 117, is set for the width of a tool for a rack of 2 inches circular pitch. The protractor is for reading the angle of the spiral.

All graduations of the straight scales read one thousandth of an inch.

In figuring gears, if any two quantities are given it will determine the third of the following: Circular thickness at pitch line, normal thickness at the pitch line, angle with a perpendicular to the axis. As a worm thread gage it will give the correct size at right angles to the thread for a thread tool for any pitch.

In operation the readings at *d* and *e* are made correct for half

standard form of thread. On the other is an opening of 29 degrees for the involute worm thread or rack cutter, and also for the Acme thread, which is at the same angle as the worm thread or rack tooth. When closed the angular sides of the openings

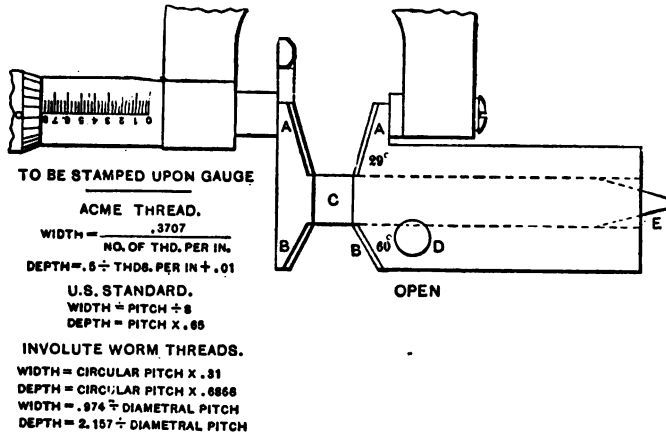


FIG. 119. — Thread Gauge.

meet, forming a sharp V, and the measuring points *AA* measure exactly .500 inch, or $\frac{1}{2}$ inch, when closed. When measuring point caliper 1 inch apart, the tail end *E* of the slide *C* is just flush with end of gage. The formulas stamped on the sides of the gage are always handy.

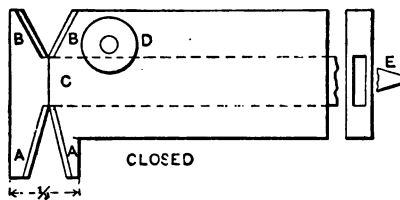


FIG. 120. — Thread Gauge.

In using the gage the proper width of point of tool is figured out by the formula and added to .500 inch. The gage is then set to the actual width of tool plus .500 inch by a common micrometer caliper, as shown in Fig. 119. Proceed in the same way for depth, except to subtract the actual depth of the thread from one inch, and set the gage by the caliper as before.

The following are some of the actual jobs done:

A hob and worm were to be made $3\frac{1}{2}$ threads per inch:

$$3\frac{1}{2} \text{ thread per inch} = \frac{1}{3\frac{1}{2}} = \frac{1}{7\frac{1}{2}} \text{ pitch; } .3" \times .31 = .093" = \text{width point of tool.}$$

$$.093 + .500 = .593", \text{ setting of gage.}$$

$$3" \times .6866 = .206", \text{ depth of thread. } 1.000 - .206 = .794" = \text{setting of gage for depth.}$$

A rack cutter was used to be shaped up of .408-inch linear pitch, to work with a spiral gear (Seller's motion):

$$.408" \times .31 = \text{width of point of milling cutter} + .500 \text{ inch} = \text{setting of gage.}$$

$$.408" \times .6866 = \text{depth of rack tooth. } 1" - (.408 \times .6866) = \text{setting of depth.}$$

A single-thread screw was to be made of $\frac{7}{8}$ -inch lead, Acme standard form of thread:

$$\frac{7}{8}" \text{ lead} = 2\frac{1}{2} \text{ thread per inch} = \frac{.3707}{2\frac{1}{2}} = .0052 = \text{width of tool.}$$

$$\text{Depth of thread} = \frac{.5}{2\frac{1}{2}} + .01.$$

The gage shown in Figs. 119 and 120 is made in the same manner as a common caliper gage; Fig. 121 shows a simpler form of this gage. A piece of sheet steel *A* is offset the thickness of the stock as at *D*. A cut is made in the offset portion of *A* for *B* to slide in. A piece *C* is riveted to *A* to keep the slide from coming away from *A*. A slot is cut in *A* for the tightening screw to slide in. We think it is preferable to have the tail end of the slide square, as shown in Fig. 121, and not pointed as in Figs. 119 and 120. Then when the gage is set for depth, an ordinary depth gage may be set for the thread gage and used for measuring the depth of thread.

GERMAN THREAD GAGES

It is the custom in a German shop to make the form of the thread on worms and spindles according to gage like that shown in Fig. 122, and this is the practice all over Germany; but as no one is able to insert the gage parallel to the axis of the screw, it

is evident that the form of the thread becomes wrong, because the shape of the thread ought to be parallel with that of the axis of the screw. The resulting error grows with the angle of the thread.

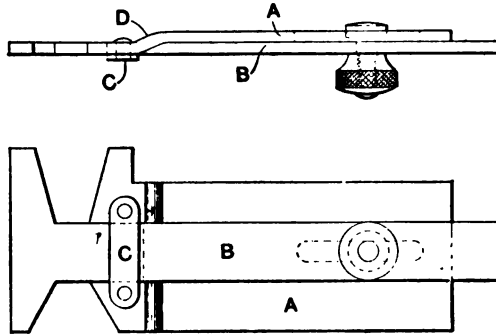


FIG. 121. — Thread Gauge.

In Figs. 123 and 124 we show how to measure the thread correctly on one line and in correct position with the radial line

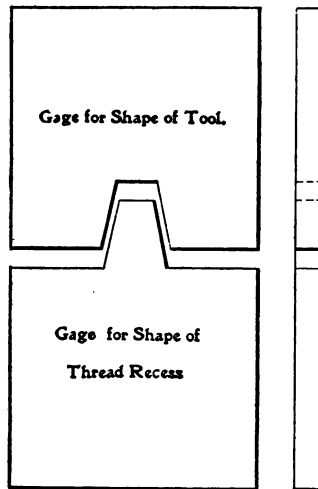


FIG. 122. — German Thread Gauge.

parallel and vertical to the axis of the spindle. The sketch is self-explanatory, the main part being the two-lipped cone of 29 degrees which is moved in the direction of its own axis, guided by its cylindrical shank. The whole piece is finished by grinding

and by preventing from turning by a dog. The two-lipped cone may be reground when worn.

The best results in manufacturing will be obtained when both gage and tool are of the same character, and we therefore

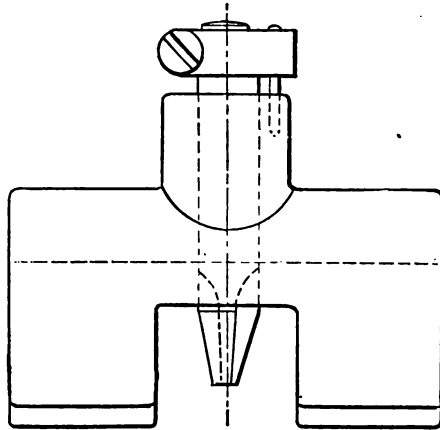


FIG. 123. — German Thread Gage.

purpose making the finishing tool similar to the cone gage. This tool is to be clamped in a tool-holder, which will fix it in correct position, one of the lips being used as a scraping tool for turning

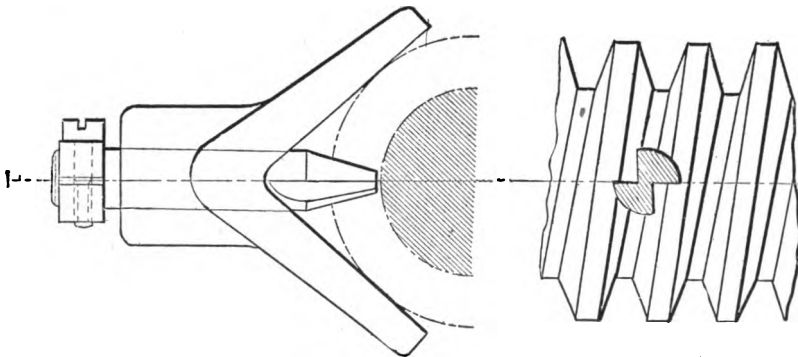


FIG. 124. — German Thread Gage.

the right-hand side of the thread in one direction, and the other lip being used for shaping the other side of the lathe running in the other direction.

Some hints for correctly making the "V" of the gage may be given: First, bore the hole for the shank of the gage and then

turn the outer surface; then after roughing out the "V" clamp the piece by the outer surface of the boss, as shown in Fig. 125; using an index plate as shown, one face of the "V" is ground. Then turn the piece 180 degrees by means of the index plate, and then with the same position of the grinding wheel grind the other face of the "V."

A PISTON-ROD THREAD GAGE

The gage shown in Fig. 126 consists of a piece *A* made of $1 \times \frac{1}{2}$ inch flat iron, with its two ends bent up about half an inch

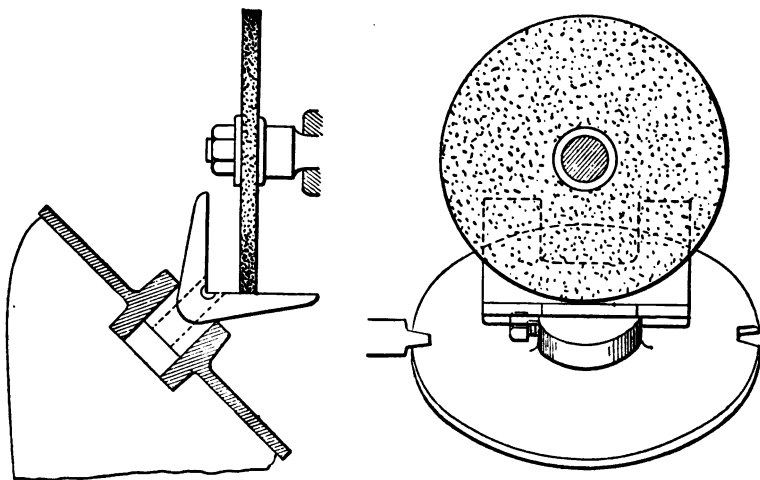


FIG. 125. — Grinding Gage.

and filed to form two V edges, which should be 60 degrees, or the same angle as the threads, in order to fit fairly to the old thread. The distance between the two should be about equal to the length of the thread in the cross-head, in order that these V's may approximately represent in the gage the first and the last thread in the cross-head.

Another piece of the same flat iron is bent up, as shown at *B*, and riveted to the middle of *A*, its free end being bent over and brought into line with the two V edges, and at such a distance from them that when a V point is filed on the free end of *B* the old thread will slip in between the three points. The piece *B* is finished by bending and filing the point until a good caliper fit

is secured, and we now have a gage which not only gives us diameter of the thread at one point, but gives us the *effective* diameter at the points where it is important for us to know it, and also provides us with means of gaging the new thread, which may or may not be of the exact pitch of the old one, but which if made to this gage will screw in every time and make a fair fit,

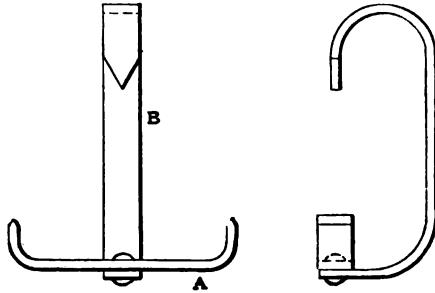


FIG. 126. — Piston-Rod Thread Gage.

which is all that the repair man on piston-rod threading expects or desires, and in fact is all that the building did in the first place.

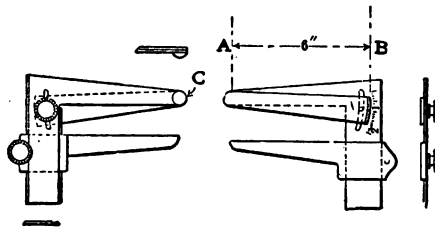


FIG. 127. — A Taper Gage.

A TAPER GAGE

The sketch, Fig. 127, shows a taper gage made some time ago, and it is one of the handiest tools imaginable. The edges of this tool must be narrow, say $\frac{1}{32}$ inch. The lower jaw slides up or down to adjust to the work; the upper one swings on a stiff joint C to adjust to the taper; both jaws are locked with thumb-screws.

As it is half a foot from A to B, the graduation is made one half size, $\frac{1}{2}$ inch reads 1 inch to the foot taper, making it read the same as the lathe taper attachment.

We will suppose that the lathe centers need replacing; set the gage on the old center, then set the taper attachment the same as the gage to turn up the new one.

The tool can be easily made by any machinist and will prove a great time and trouble saver in the shop.

MICROMETER DEPTH GAGE

We show a micrometer depth gage which was constructed some time ago, and which has since been in frequent use. It is inexpensive to make, and seems to have points of advantage over some other tools used for the same purpose. The frame may be a malleable iron casting, or may be milled from soft steel case-hardened, and the base ground true.

Fig. 128 is a side elevation, and Fig. 129 a plan and partial section on the line *M M*, Fig. 128.

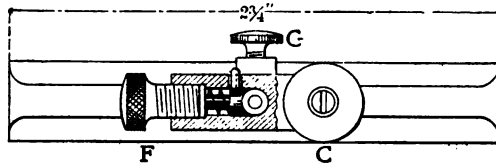


FIG. 129. — Micrometer Depth Gage.

In Fig. 128 it may be observed, first, that the sliding rod *A* is graduated with fine lines running entirely around and $\frac{1}{4}$ inch apart. Second, the sliding piece *B* can, by means of the micrometer nut *C* and screw *D*, together with the spring *E*, be given a movement on *A* of $\frac{1}{4}$ inch; third, an indicator point on *B* traverses graduations on the side of the frame. These are .025 inch apart, corresponding to one revolution of *C*. Fourth, there is a line on *B* where *A* is exposed, that may be adjusted opposite any line on *A*. Fifth, one end of *A* has a large and the other a small contact face; either end may be used down. Sixth, inserted in the lower end of *D* is a small broad-headed screw, forming a shoulder against which *B* is held by the pressure of the spring *E*. This shows better in Fig. 130.

Fig. 131, which is a plan of sliding piece *B*, shows the manner in which *D* is held adjusting in *B*. This is similar to the clamping device for the anvil adjustment on the Brown & Sharpe micrometer. The tapped hole for the screw is counterbored, as shown

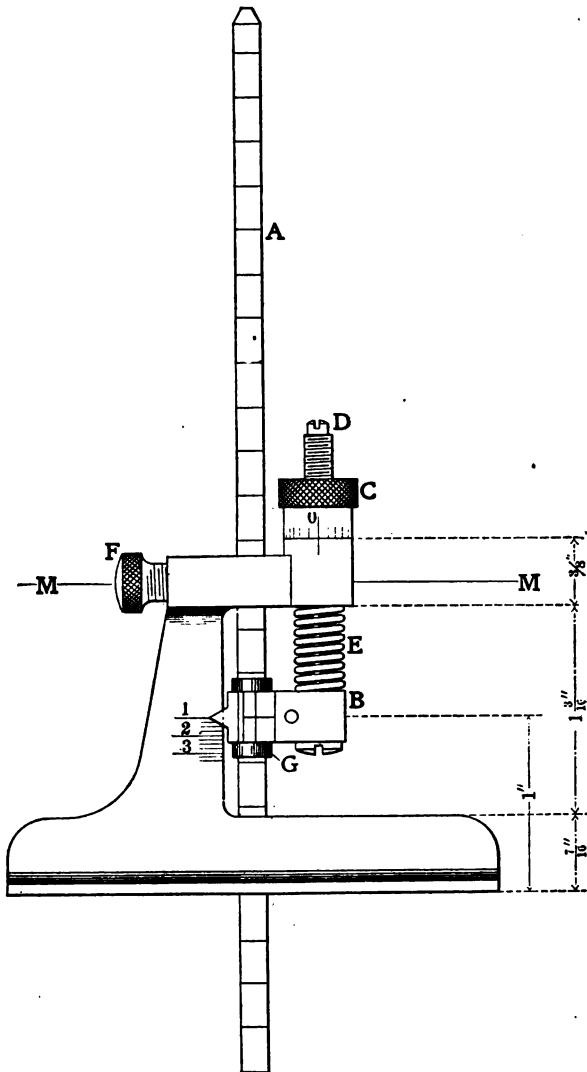
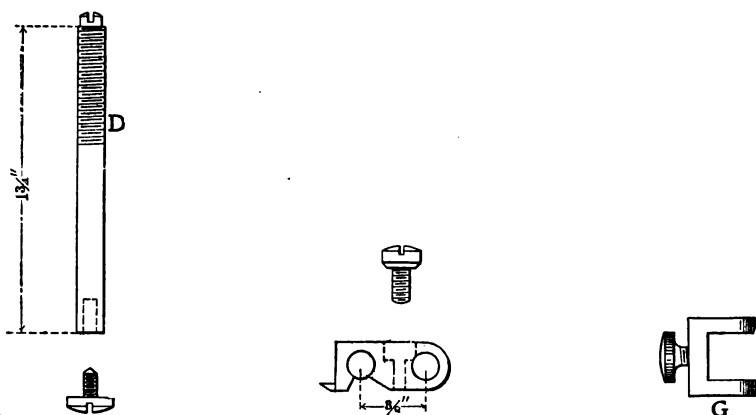


FIG. 128. — Micrometer Depth Gage.

by the dotted lines, and is so situated that a portion of the screw head binds against *D*, making a very rigid connection.

G, in Figs. 128, 129 and 132, is a U-shaped piece embracing *B*, each leg encircling rod *A*, and is provided with a set-screw to tighten against *B*. This is used to clamp *B* to *A* when desired.

Fig. 129 shows the device for clamping rod *A* in the frame. The knurled screw *F* acts against a small shoe, the face of which conforms to the round surface of *A*. On this shoe is turned a stem which is encircled by a coil spring, one end of which presses against the screw *F*. This spring keeps a constant pressure of the shoe against *A*, which is quite important. In the side of the shoe can be noticed a small pin inserted, which slightly protrudes



FIGS. 130, 131, and 132. — Details of Depth Gage.

through a slot in the frame. This is to enable the shoe to be held back by the thumb-nail while *A* is being reversed.

Two methods of measuring depths with tool are apparent: One is to clamp *B* to *A* at a suitable line, then operate by means of nut *C*. The contact is felt very distinctly, and the nut may be turned a little too far and then turned back lightly until it stops. When used in this way the tool is very sensitive. The spring causes an ideal contact between *A* and the work. Or the rod *A* may be used independently and slid down to contact and tightened with knurled screw *F*. The nut *C* may be adjusted till the lines match and the reading is taken.

When *B* is clamped to *A* at a suitable line, the gage is very handy to apply to the work as it progresses, when the exact

amount still to be planed or milled off can be seen at a glance. Or the micrometer can be set at the proper reading, and the rod used independently. Then the amount still to be removed can be judged by noting the proximity of the line on *A* to that on *B*.

This tool can be adjusted for wear at any time, by setting a flush end nut *C* at zero, then loosening the binding-screw in the back piece *B*, and turning with a screw-driver until the lines on *A* and *B* coincide, then resetting the binding-screw.

In making the graduations on the frame they should be so placed that the operator will bring the indicator point practically opposite 0 or .050 inch.

MAKING AN ARMATURE TEMPLET

In making armature segment templets, a little money spent at the start will prove a source of great saving when it comes to handling the thousands of punchings when assembling the machines; therefore we will describe in detail the best practice and the way to go about it.

The placing of the dovetails is one of the essential points, but the location of the slots is equally important, as when assembling the punchings in the machine in any way the slots must line up. The method we are about to describe of making these templets is based on a system of reversing on six accurately located pin-holes, and not filing to any lines but working entirely to a gage and plain external measurements. The pins for the six holes are $\frac{3}{16}$ inch diameter, but 1 inch long, hardened, ground and lapped, and all exactly the same size. The end driven into the templet is perfectly flat, with only the extreme corner taken off with an oilstone; the other end is beveled off to about $\frac{3}{16}$ inch diameter, so that, when driving, a slightly slanting blow will not drive the pin in crooked.

We are now ready to describe the method, and will use the templet shown in Fig. 133 for reference; it is to have 36 slots and 12 segments complete the circle.

For the templets, of which we will make two — an original and a duplicate — we will take $\frac{1}{8}$ -inch sheet brass, which we will hammer flat on a plate with a mallet. Then we will lay the two pieces one on top of the other, and in some out-of-the-way place near each end, as *a* and *b* in the sketch, we drill two $\frac{3}{16}$ -inch holes

for two rivets. We now rivet the two plates together, and with a bandsaw saw out approximately the radius and dovetails so as to relieve some of the strains before we put any accuracy into the templets.

Now they are put on the radial planer, and the outside edge planed, and the inside marked to correct radius, by taking a sharp-pointed side tool and running in about $\frac{3}{8}$ inch, with the square side towards the templet; this groove is used as a gage to which it is easy to file the inside. As the templet is now planed we must next determine the center distances of the dovetails *A B*, which is the most essential step and the basis of the whole templet.

About the place we want to locate the dovetail at *A*, we drill and ream a $\frac{3}{16}$ -inch hole as shown. The location of this hole is

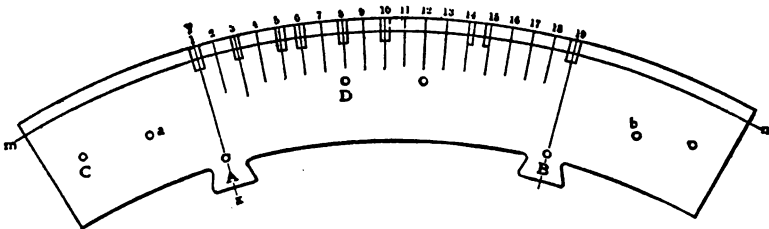


FIG. 133. — Making an Armature Templet.

not particular, only it must be a straight, smooth hole through both templets. Into the hole drive one of the six pins spoken of before.

Now measure the distance from the outside planed edge to the center of the pin, which can be done accurately, and subtract this from the outside radius; figure the chord from an arc of that radius having 12 segments to the circle.

$$\text{radius} \times \text{sine of } \frac{360^\circ}{2 \times \text{number of segments}} = \frac{1}{2} \text{ chord.}$$

Having figured the length of the chord, add .375 = diameter of bushing of jig shown in Fig. 134, to the chord, and set the jig accurately by measuring to your figures.

Next slip one end of the jig over that one pin in the templet, and place the locating arm on the bushing; and adjust it so that it will just touch the outer curve edge; transfer the arm to the other bushing, and locate the jig and clamp. Now drill and

ream the pin-hole at *B*. Since the templet depends on these two pins as centers, there is no chance for any errors in the center distance of the resulting dovetails. Drill another pin-hole somewhere near the point *C*, and through both templates by driving out the two rivets. We have now drilled three holes without laying out; for locating the fourth hole, *D*, we reverse the duplicate templet on the line αy , and drive in the pin on the dovetail, then line up the planed edge with a square to shut out light, clamp the templet and drill through the original, using the drilled hole in the duplicate as a jig, and vice versa.

Now we have the three pins *A*, *C*, *D*, so reverse the duplicate, bring dovetail *A* under dovetail *B* of the original, and using

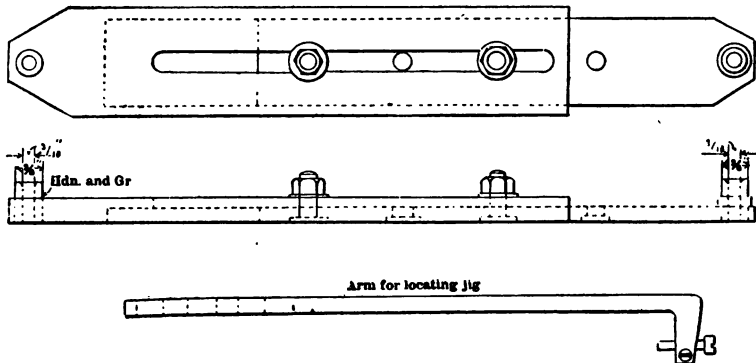


FIG. 134. — Making an Armature Templet.

the drilled holes in each templet for a jig drilled through the other templet.

We now have all six holes drilled, the last four in correct relation in the two accurately located dovetail pin-holes, which we distanced by measuring machine measurements; therefore we have the foundation for an accurate templet, as the rest of the templet is derived by reversing on the six pins.

Now upon the original we will lay out the dovetails and slots approximately, which is not difficult. Place a center square on the outer edge, put a half pin in the dovetail pin-hole, place the blade of the center square against this, draw the radial line αy , and from this line proceed with the laying out. The next step is to drill and counterbore out the stock in the slots, after having again pinned the two templates together. There is not much

danger of springing the templet by removing this stock, as a rib, not shown in the sketch, is left intact at the upper end.

A counterbore $\frac{1}{4}$ inch small is plenty small enough, as with a little care in laying out, the slots will not be out that much.

For filing the slots and dovetails, so as to insure their being perfectly straight and square, we use the filing jig, Fig. 135. This needs no explanation, except that the two screws, *E* and *F*, against which the outer edge of the work rests, are adjusted so that the hardened steel plates on the jig will always take a position that will make the sides of the slots parallel.

Before the filing place the original templet on top of the

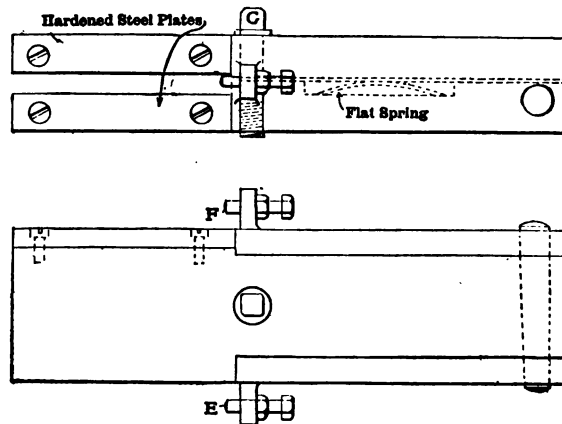


FIG. 135.— Making an Armature Templet.

duplicate and drive in the two dovetail pins; and in order to make it firmer drive in two more pins in any of the other two holes. Next place the jig with the hardened plates on one side of the slot, which is on the radial line with the dovetail (slot No. 1, Fig. 133). Use the laying out again only as an approximation, and, to allow for errors, place the jig about .010 inch from the line representing the edge of the slot; then clamp the jig by tightening the screw *G* passing through the jaws, file the slot down to the hardened plates on the jig, and then remove the latter.

Now drive out the pins and reverse the duplicate on the line *xy*, which will bring our filed side of the duplicate under the unfiled side of the original, and vice versa. Now by means of a straight-edge set the filing jig even with the filed surface, and file

through the other templet; then with a micrometer and inside caliper obtain the width of the slot now filed. If it measures .010 inch too small, place the filing jig on again, and with a .005-inch thickness gage and a straight-edge set the jig to take off .005 inch, and then bring the templets back to their original position and file out the other side, using the surface just filed on one templet as a gage for setting the jig. Now this slot is right up to plug size and reversible. In just exactly the same way we locate this we file the dovetail, only we have a dovetail gage instead of working to measurements. Now we have one slot and one dovetail complete on both templets; by simply reversing the duplicate we can bring and finish slot and dovetail under the unfinished slots and dovetail of the original, and, using the former as a guide to set the filing jig to, we finish that dovetail and slot. Now we have two slots and both dovetails finished and exactly reversible and all center distances correct.

Next comes the spacing of the slots: Since the templet has eighteen slots between the dovetails, then there is one slot just half way between the two dovetail slots. This slot is numbered 10 on the sketch, and it is a simple matter to get it exactly in the center by simply using the reversing method just described. Now we have two dovetail slots, and this central slot in both templets complete. There is no slot central between No. 10 and No. 1, but we find there is a rib; the trick is to get this rib just the right thickness so the rest of the slots divide up evenly. To do this proceed as follows:

With a scratch gage and the planed surface as a guide, draw an arc 1 inch from the planed surface clear across the templet, as shown at *m n*. Subtract this 1 inch from the outside radius and figure the width of the rib at its intersection with this line.

It is plenty close enough to figure the chord between the centers of two slots and subtract the width of the slot; the remainder equals the thickness of the rib at the intersection of the line *m n*.

Make a little snap gage of a piece of metal exactly this figure size, and file the rib by the reversing method described before, only instead of reversing on pins, use two flat plugs in slots 1 and 10, and a pair of parallel clamps. The ribs can be filed very accurately to size, as it has a slight taper, generally about .008 to the inch; so if the gage slides to within $\frac{1}{8}$ inch of the arc, there is .001 inch yet to come off the rib.

When the rib has the right thickness and is reversible, we finish the other side of the slot by placing our filing jig just the right distance away to make the slot the right size.

We have now slots 5 and 6 finished; upon investigation we find that in between the slots 1 and 5 is a central slot, 3; we get this slot central by reversing, using our flat plugs in holes 1 and 5. Slot No. 8 we get in the same way. Slots No. 2, 4, 7, and 9 we use our little sheet metal snap gage again.

The slots from 1 to 10 are now finished and correct, and by reversing these ten slots into different positions and using them as gages to set the gage to, we file the incompleted slots.

A templet made in this manner is accurate in every detail, can be reversed, and slots can be shifted in any way, and there

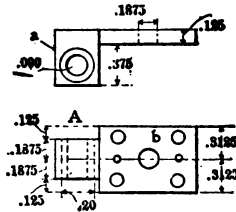


FIG. 136. — A Locating Templet.

will be no greater error than $.001$ inch anywhere. A templet, as described above, is generally completed in from forty to fifty hours.

Another advantage of duplicate templates is, the duplicate can be used in making the die, thus saving the original as a master.

MAKING A TEMPLAT FOR LOCATING PARTS

Piece *A*, Fig. 136, is a templet that was used on a certain operation in experimenting to locate certain parts accurately from a bushed $.090$ hole in wing *a*, to a $.1875$ hole at right angles to it. The four holes in *A* are body size for 10–32 screws, and need not be very close; the piece that goes on is located by the $.1875$ hole. Wing *a* was hardened up as far as we could without hardening the thin part. There were nine of these wanted. There was nothing out of the ordinary in machining them in the soft stage; they were left about $.025$ inch large, and this was found more than enough to finish to size.

The first thing we did was to lay out the four 10-32 screw holes fairly close, as we were going to use them to work piece *A* from. The hole for the bushing was laid out approximately between surplus stock; this hole was drilled and reamed on a drill press, and the screw holes were drilled; then wing *a* was hardened and the hole lapped for the bushing. There were fifteen bushings made to get what we wanted. In testing roughly, we used an indicator test, and threw three of them away right off; and with the flat surface test with a finish hole cast out two more, which left us one extra one. This sounds extravagant, but we don't think it was so, considering what would have happened if we had not detected the poor ones in time. The bushings were first rough lapped, then rough ground on the outside, so they would fit a holder with a round hole to clamp them while we were lapping the hole. This is good practice on bushings, for if

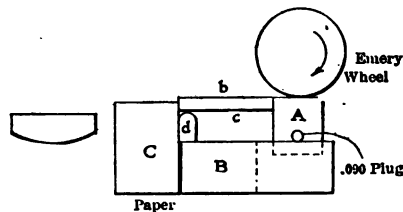


FIG. 137. — Grinding Surface Parallel.

there are any surface strains you take them out, and you hold the work as true as you can get it.

After finishing and tapping the bushings home we ground surface *b* parallel with .090 plug in Fig. 137, and the proper distance from it, using a piece of gray iron milled out for the wing to enter, with a sixteenth play on the side. Piece *B* was ground in place on the magnetic chuck, so as to make contact with the other pole through a loose piece of iron *C*, with paper between *B* and *C*. Piece *d* is a block to rest *A* on while grinding *b*, surface *C* being ground parallel with *b* by resting *d* on the chuck. About .002 was left to finish and correct errors liable to show in the squaring-up test.

The work was then taken to a lathe with draw-in chucks. Fig. 138 is a plan of the face-plate, with a floating or false plate attached with screws or straps. The floating plate was faced off true, and a $\frac{1}{4}$ -inch hole drilled through to let a pin held in the

chuck and turned down to .1875 inch stick through far enough to set piece *D* properly; the required distance being obtained between the .090 plug placed in *D* and the .1875 pin just turned, by using a templet (shown by dotted lines) of the right thickness to go between them. The wing *a* (Fig. 136) was set approximately central with the .1875 hole with an adjusting screw, tapped through one side of piece *D*, as in Fig. 139. In setting wing *a*, we used a line drawn across surface *C* (Fig. 137) central with the wing; then with a fine point set central, and turning the spindle half way around, we set the setting piece. Piece *D* once set was

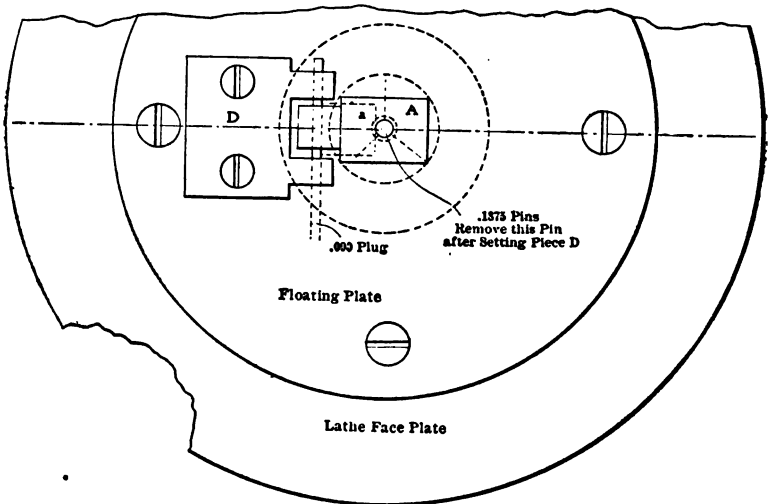


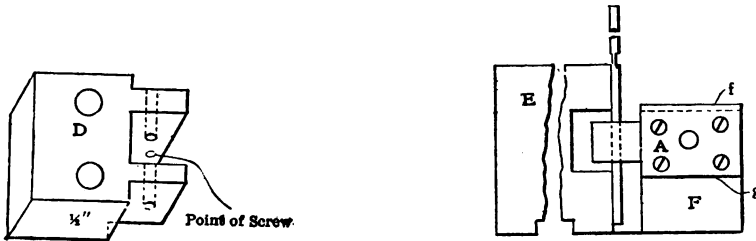
FIG. 138. — Work Located in Lathe.

not disturbed. We had to move the adjusting screw to keep within our surplus stock. Using a light strap to hold *A* up against the adjusting screw point, with the .090 plug in *A* and *D*, we drilled and bored the holes to size.

Piece *D* was finished the right distance from the bottom up to the plug .090, and used as a gage to test *A* when grinding surface *b*, Fig. 137; it was made of gray iron, and the .090 holes were not bushed.

Block *E*, Fig. 140, is gray iron, with face *e* square with the bottom. The channel is the right height to allow the .090 hole to be squared up by using a plug about $1\frac{1}{2}$ inches long, and tapping *A* up or down until it shuts out light in any of the three

positions possible when on grinding block *F*. We used 6-32 machine screws to attach piece *A* to block *F*, and after it was tapped square with *E* ground surface *f*; and then turned the piece over on the other face, squared the plug and ground surface



FIGS. 139 and 140. — Details of Templet Making.

g. Surfaces *f* and *g* at this stage are parallel, but unequal distances from the center of the .1875 hole. Angle *G*, Fig. 141, is what we use for measuring from a plug up to a narrow edge. Piece *A* is shown in position to be measured over points marked *a* with a micrometer. The angle *G* is hardened steel, ground

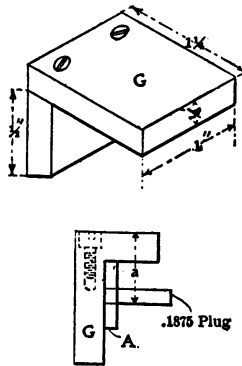


FIG. 141. — Details of Templet Making.

and lapped and assembled as shown. After measuring these pieces, we tested them by putting them on a plug, and seeing then if they would reverse without the edges falling or rising. Wing *a*, Fig. 136, was ground roughly, leaving .0005 on a side; then a finishing cut of .0003 was taken, which left .0002 to lap — which is all we want on a piece like this. Surfaces *f* and *g*,

Fig. 140, rested on a chuck, and surfaces *b* and *c* between two square parallels when grinding wing *a*.

The work was tested at every stage in making these templets in this way.

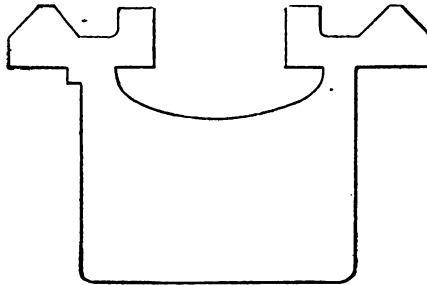


FIG. 142. — Lathe Bed.

TEMPLETS FOR PLANING A LATHE BED

A templet or gage is first made to prove and secondly to bring work to a standard. The manner in which these gages are made often causes a great difference in the time consumed in fitting.

The superintendent was a good mechanic and a nice man to work for, but the shop was new, and he had much to contend with. When the better templets were shown to him, he at once allowed them to be made. In Fig. 142 is shown the end view of the lathe bed, and in Fig. 143 the templet first made. This was required to fit the V's and the flats at the same time.

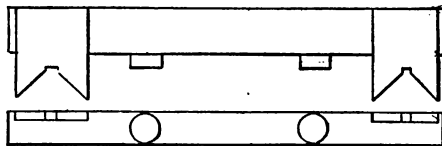


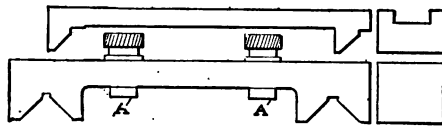
FIG. 143. — Lathe Bed Templet.

The body of this templet was made of 1 x 2 inch machine steel, with V's cut in $\frac{1}{4}$ -inch tool steel plates. One inch round stock was turned down on the ends and set in to give the height of the flat bearings, as shown.

In using this templet it was necessary on account of its narrow bearings to use a square to line it up across the bed, and also vertically. It was a very slow job of cut and try, until the

templets, Figs. 144 and 145, were made. After the bed was roughed out, the proper distance from the first side of one V to the first side of the other was obtained by the use of the half templet, Fig. 144, then the other two sides of the V's were finished until the whole templet, Fig. 145, rubbed chalk marks off the four sides of the V's.

The flat bearings were finished last. The hardened steel plugs *A A* in templet, Fig. 145, were fitted so as to hold paper between their faces and the job. The templet for planing the tool carriage was of course just the reverse to Fig. 145. The saving of time in using the last templet was over 3 to 1.



FIGS. 144 and 145. — Lathe Bed Templet.

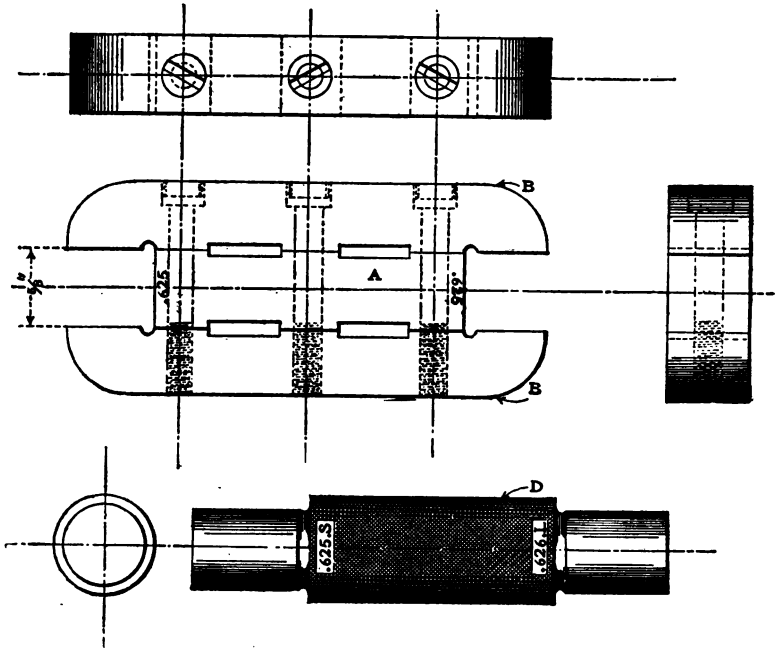
A PERMANENT SNAP GAGE

The snap gage shown in Figs. 146 and 147 consists of jaws *B B* and center piece *A*, the latter being exact width of dimension desired. After pieces *B B* have been ground and lapped, they are put together by means of screws, as shown. Plug *D*, Fig. 148, is a good gage to test the snap gage with.

In constant use a gage of this kind will wear, especially if used to test round pieces such as would naturally be turned and twisted in the gage, and give rise to hills and valleys. This may be detected by a plug gage, as shown, one of which is the same size as the snap gage, and the other end .001 or .0005, or any limit that may be established, larger. When the big end of the plug will enter the snap gage, it should be taken apart, ground if necessary, lapped and put together, when we have again a new gage with a little or no gage expense. One end of the plug is marked size by *S*, the other end limit by *L*.

This is no doubt a very superior form of gage. Its great merit lies in the fact that the more expensive piece *A*, which determines the size, is not subject to wear, while the correction of the gage when worn does not involve any expensive work, by merely the resurfacing of pieces *B*. The screws should be a loose fit in *A*, to avoid any tendency to swell that piece. Most of

these gages that we have seen (and they are the accepted form of gage in some leading and first-class works) have but a single end, two screws only being used and one end of *A* being extended beyond the jaws to form a handle, thus making a gage which is more like the usual form. The construction shown has the advantage that at a trifling additional expense two gages are made. It would, however, be obviously impracticable to make these of different dimensions to act as limit gages.



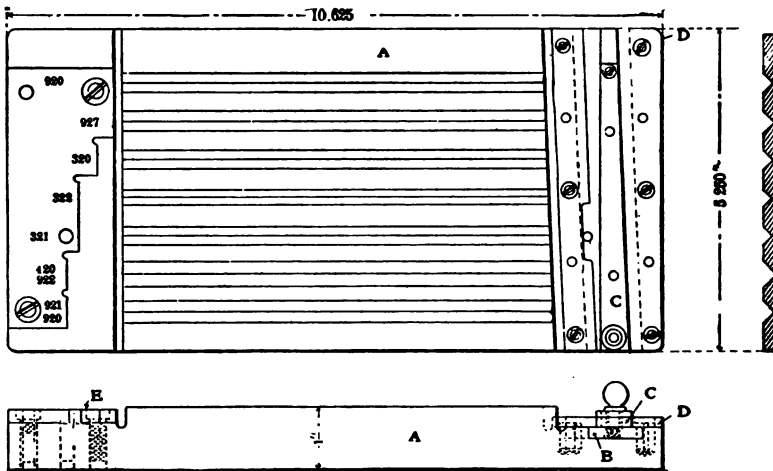
FIGS. 146, 147, and 148.—Permanent Snap Gage.

ROD GAGING FIXTURE

Having to gage for length a number of steel rods of various diameters and lengths, and it being necessary that there should not be more than one-thousandth variation either way, the gage in Figs. 149 and 150 was devised to detect the slightest inaccuracy of length.

In a gray-iron base block *A* were cut a series of V-grooves of depths according to the diameter of the style of shaft for which each was intended. At one end of *A* a groove was cut a slight

angle; running freely in this groove was a steel strip *B*, screwed to which was a steel block *C*, having a hardened and ground face, which was square with the grooves in the base. At one end of *C* were placed graduations, and also on the slide plate *D*. At the other end of the block *A* was fitted a hardened and ground steel block *E*, which received one end of the shafts and was cut away according to the lengths of these. A shaft to be gaged was placed in the groove which bore its number, and the block *B* advanced until the face of *C* contacted with the end of the shaft, the vernier marking on the end of the block then showing whether the shaft length was to the required degree of accuracy.



FIGS. 149 and 150. — Rod Gaging Fixture.

A PLANER GAGE

The sketch, Fig. 151, shows a gage which is perhaps a little out of the ordinary; it is used to gage the width of planer beds, the top rails being planed to a similar gage, and the object being to jig the side screw holes in the top rail.

The main casting *A* floats in the blocks *B* which rests in the V's of the planer bed. These supports are about 6 inches long, and serve to keep the gage screw with the tracks.

C and *D* are hardened and ground steel disks, held in positions by flat-head screws. Opposite these disks are two holes through the casting *A*, fitted with hardened bushings and plungers

E and *F*. The outer end of the plungers and bushings are ground flush when the gage is set to the standard size, or $22\frac{1}{2}$ inches.

The method of getting this size may be of interest, the available tool being a 12-inch vernier. Two pieces, *G* and *H*, were turned and fitted to a bushing, the ends square to $11\frac{1}{4}$ inches, and two pointed screws used to draw the ends together, as shown. This measuring rod was used between the points *C* and *D* and *E* and *F*, first getting *C* and *D* square with the inside of the gage.

The general dimensions of the casting *A* were as follows: Main web and cross ribs, $\frac{1}{4}$ inch thick; outer rim, $\frac{1}{4} \times 1\frac{1}{4}$ inches; inner rim, $\frac{3}{8} \times 1\frac{1}{2}$ inches, except at supports, where it is $\frac{1}{2} \times 2\frac{1}{2}$.

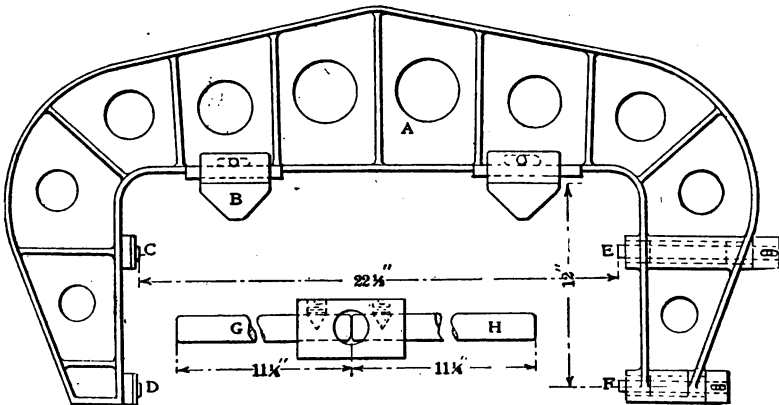


FIG. 151. — Planer Gage.

GAGES FOR TEXTILE MACHINE WORK

Fig. 152 shows the gages used in the manufacture of spindles for textile machinery.

When a drawing is received for a new spindle, the first thing done is to make a sample, which is used as standard for all others of that kind made. Hardened and ground plugs are made for the different diameters and tapers, and are used to make the gages from and for testing the gages.

For grinding straight work over 4 inches in length ordinary yes-and-no ring gages are used. The operator also has a try-gage, like *A*, made from $\frac{1}{4}$ -inch stock, thickened to $\frac{3}{8}$ inch at the contact points. The operator uses this gage without removing the work from the machine. When this gage will go over the

work easily, the operator removes the work from the machines and tries his yes-and-no gages, which have a limit of .0015 inch, and he rarely has to put the work back in the machine. As the gage wears it is peened at *a* to bring it back to size.

At *B* is a spindle on which the taper has to be ground very accurately, and the gage has to be a certain distance from the

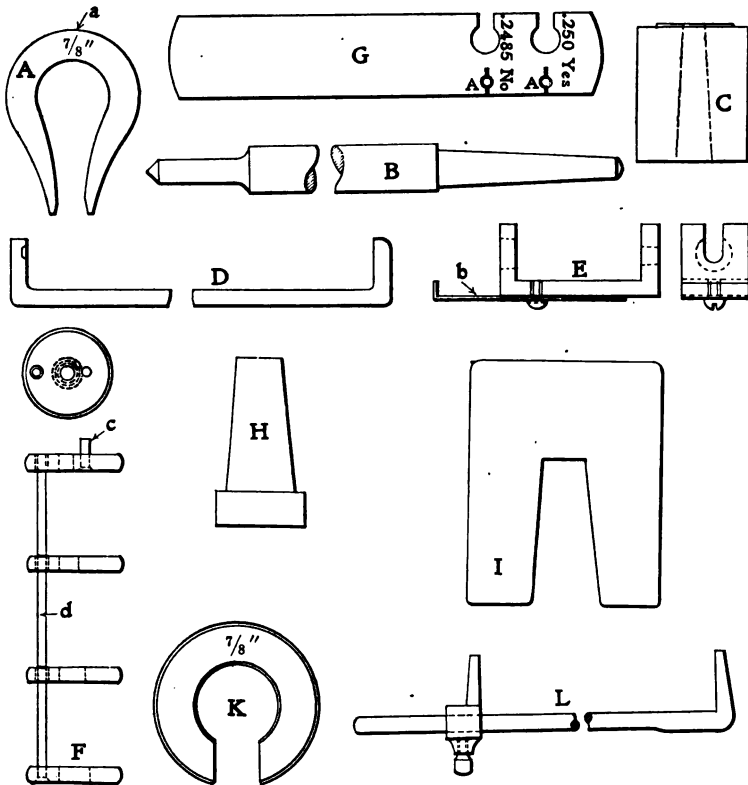


FIG. 152. — Gages for Textile Machine Work.

extreme point within the limit of .01 inch. Three gages are used, *C*, *D*, and *E*. *C* is the ring gage to get the taper by, and has a step on top .01 inch high. *D* is the spanner gage to get the length by, made from $\frac{1}{2}$ -inch square stock. *E* is the try gage. The slot is cut in the top so that it will slip over the center, so as not to back the center off when trying the gage. When the operator rings up the machine for grinding this taper, he first

grinds one spindle to size, and then adjusts the little piece of steel *b*, so that it will just rub against the side of the rest. This gage will then show every time when the work is down to size. In grinding each piece, he uses this gage, and when he feels it touch the rest he removes the work and tries his ring gage, and then his spanner, which has to touch on the lower step, but not on the top one; anything between the two is all right.

The gage *F* is the one used for gaging, our taper grinding up to $\frac{3}{8}$ inch diameter and 6 inches long. When taper and size are correct the end of the spindle will come flush with the top of wire *c*, the top ring will be flush with the wire *d*, and the two middle rings will be flush with the marks on this wire. For small, accurate work this gage can be recommended. As the gage wears, the wire *c* can be driven out and a longer one inserted, and if the holes do not wear equally, the ones that wear least can be polished out. All of our gages for lathe work up to $\frac{1}{2}$ inch are made like *G*, but with only one hole, the roughing gages being made with point contact and the finishing with line contact, as shown.

For gaging taper work, like *H*, on the turret lathe, we use a gage like *I*, and the taper is determined by placing the gage on the work and holding up to the light; the size is determined by the gage touching both the taper and the shoulder on work. On lathe work above $\frac{1}{2}$ inch we use the gage *K*, made from $\frac{3}{8}$ -inch flat stock. For pointing to length we use an adjustable spanner gage like *L*, made from round stock.

These gages are all easily and cheaply made, and fulfil all the requirements of spindle making, and will perhaps be of use to others.

SECTION V

INSIDE MICROMETER CALIPERS AND OTHER GAGES FOR INTERNAL MEASURING; THEIR CONSTRUCTION AND USE.

MAKING SMALL INSIDE MICROMETER GAGES

THERE are now on the market numerous different makes of inside micrometers and inside micrometer gages, the smallest measuring as small a hole as $\frac{1}{8}$ inches. Now all machinists know that there are more holes bored below $\frac{1}{2}$ inches in diameter than over $\frac{1}{2}$ inches. But so far none of our tool manufacturers has undertaken to fill the demand for measuring tools for these small diameters, although we all agree that closer measurements can be taken with an inside micrometer gage than with an inside caliper.

Tools of this kind for small sizes can be made cheaply and would soon find a market. For making a micrometer gage to measure from $\frac{1}{8}$ inch up, let us take a piece *A*, Fig. 153, of $\frac{1}{8}$ -inch machinery steel, put it in the lathe with a spring chuck, center it and drill a hole $\frac{1}{4}$ inch deep for tapping, with a $\frac{1}{8}$ -inch tap, 40 thread. Then take a wobble drill, or rather make it of a piece of Stubbs' steel; flatten and grind it out of center. Drill with this $\frac{3}{8}$ inch deeper, and then tap it and turn a short taper *a* and thread it with a fine thread, cut it off $\frac{1}{2}$ inch long, turn it around in the chuck, and round and polish the end with a radius less than $\frac{1}{4}$ inch. With a thin milling cutter split the piece at *a* into four jaws. Make a small knurled nut *D* to fit at *a* for closing the jaws. Case-harden this sleeve on the large end. Next cut the same thread that we have in the sleeve on a $\frac{1}{8}$ -inch Stubbs wire; round one end and cut it off $\frac{1}{2}$ inch long. On the round end of this screw *B* file a head, as at *C*, and harden this end.

For a wrench to turn the screw make a round disk *E* $1\frac{1}{4}$ inches

diameter, $\frac{1}{8}$ inch thick, with a hole in the center to fit the end of screw *B*, and graduate the disk into twenty-five equal parts to correspond with our 40 threads on the screw, and thus read to thousandths of an inch. Harden the disk around the hole. Next make a handle *H*, 4 to 6 inches long, to hold the sleeve *A* when measurements are taken. At *F* is riveted an indicator or hand that swings on the handle, and has an edge that points to the thousandths on the disk.

With an outside micrometer and disk *E* for a wrench, we turn screw *B* in the sleeve *A*, and set it to any size from $\frac{1}{2}$ to

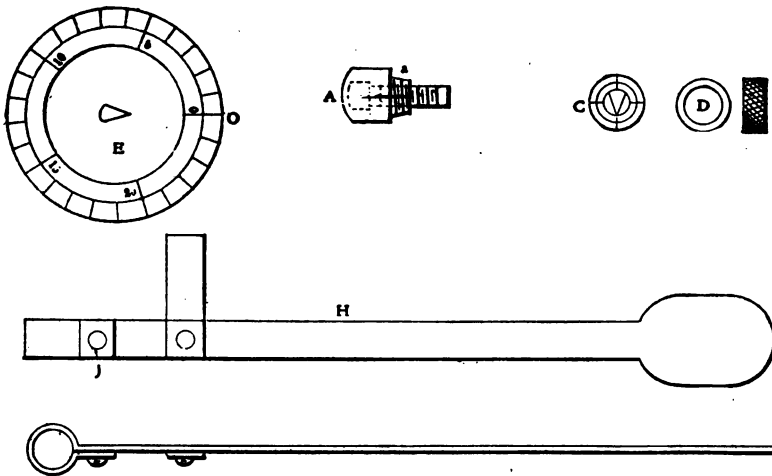


FIG. 153. — Small Inside Micrometer.

$\frac{1}{8}$ inch, and lock the screw by the knurled nut *D*. Or we place the pointer on the handle to match at zero on the disk when screw is turned into the sleeve, and the tool measures $\frac{1}{2}$ inch, and lock the handle with screw *J*.

We now have a micrometer for inside measurement within the limits of $\frac{3}{8}$ inch. If we make another sleeve *A* $\frac{1}{2}$ inch long, drill and tap as before $\frac{1}{2}$ inch deep, and in this fit a screw $\frac{3}{8}$ inch long, and use the same disk, handle and nut, we can then measure a hole from $\frac{1}{8}$ -inch diameter to 1 inch, and still with $\frac{3}{8}$ inch of screw left in the sleeve, giving it a good, steady hold when locked with the knurled nut. The next largest sleeve should be $\frac{3}{4}$ inch deep, and a screw $\frac{3}{4}$ inch long, drilled and tapped $\frac{3}{4}$ inch long. This would enable us to measure from 1

to $1\frac{9}{16}$ inches. And still another sleeve $1\frac{1}{2}$ inches long, with its screw the same length, would measure from $1\frac{9}{16}$ to $2\frac{5}{8}$ inches.

This makes four sleeves, but all being small and made of soft material and case-hardened, they could be made at little expense in a screw machine even; the same disk and handle and nut being used for them all, if we wish. One advantage with them is that we can reach into very deep holes and still have a sensitive and reliable measuring tool. One disadvantage is that the screw is

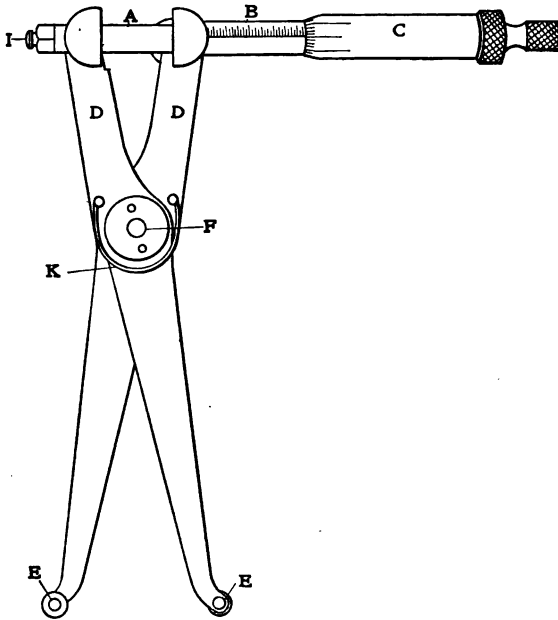


FIG. 154. — Inside Micrometer Assembled.

exposed to dust and scratches, the same as older styles of outside micrometers; but this can be prevented by having four or five split brass sleeves, which are easily made to slip over the screw and cover most of it.

AN INSIDE MICROMETER

The half-tone, Fig. 154, shows an inside micrometer assembled. Its capacity is from $\frac{1}{2}$ inch to $3\frac{1}{2}$ inches. Fig. 155 shows details.

The two members *D* are made of flat tool steel, .070 inch thick. The three holes, *EFG*, are drilled in line, the distance from *E*

to F being twice the distance from F to G . The locating and finishing of these holes must be done with the greatest care, as upon them the accuracy of the tool is to a great extent dependent.

The upper parts of the members D are filed away, so as to leave G a little more than half a hole. The trunnions H of the swivels A and B fit in the hole G , and the swivels A and B cannot fall out of G unless they are swung around in line with the members D .

The swivel A goes in the left member D , as shown in the half-tone. Its barrel is .250 inch outside diameter, and is bored .172 inches — a sliding fit for the end of the micrometer screw L .

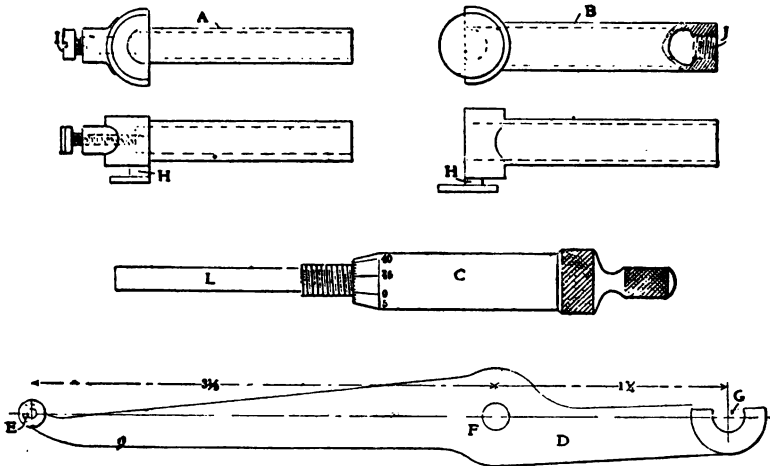


FIG. 155. — Details of Inside Micrometer.

The swivel A is also provided with an adjusting screw I to take up wear.

The swivel B is bored .250 inch — a sliding fit for A ; the rear end of B is threaded at J to form a nut for the micrometer screw. The outside is .310 inch diameter, and is graduated as shown in the half-tone, the inch spacing being of course only $\frac{1}{2}$ inch apart because of the two-to-one ratio of the legs D .

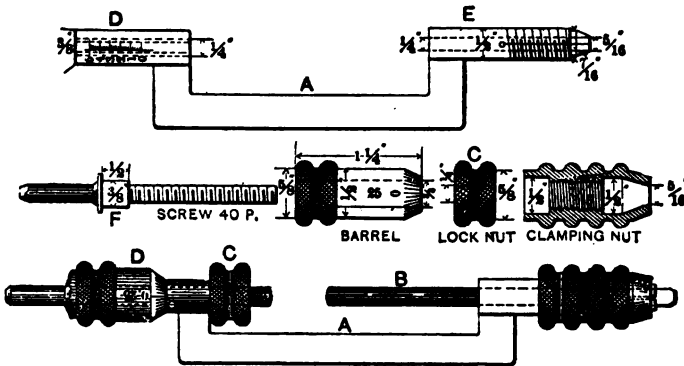
The thimble C is bored .310 inch to fit over B . It is .40 inch outside diameter, and is secured to the micrometer screw in the usual way. The micrometer screw, .250 inch diameter, is threaded forty threads per inch. The thimble is divided into fifty spaces instead of twenty-five, for the same reason that the inch graduations on B are half an inch apart.

The contact points of the instrument are disks $.250$ inch diameter, with rounded faces. The ends of the members D are counterbored at E to receive a small projection on the side of the disk, which is fastened in place by a small machine screw. When a disk becomes worn, it may be turned around so as to present a new face to the work. The U-shaped spring K keeps the end of the micrometer screw L in with the adjusting screw I .

With this rule measurements within $.001$ of an inch may, with practice, be made.

INSIDE MICROMETER CALIPER

In Figs. 156 and 157 are contained sketches of an inside micrometer caliper which is quite easy to make, and is very useful



FIGS. 156 and 157. — Inside Micrometer for Shrink Fits.

in making shrink fits, etc. The frame A is a brass casting made in the form shown to allow a considerable adjustment of rods B and also to make a place for the lock-nut C . One end of the frame D is drilled out with a $\frac{1}{4}$ -inch drill, and tapped with a $\frac{3}{32}$ tap (special). The other end E is drilled $\frac{1}{2}$ inch to receive the rods. The frame is placed on centers; the end D is turned to $\frac{3}{8}$ inch, and the end E to $\frac{1}{2}$ inch, and is threaded and tapered as per sketch.

The barrel and screw are made separately, the barrel being shrunk on the screw at F . The screw has 40 threads per inch, and is $\frac{3}{32}$ inch at top and $\frac{1}{2}$ inch at the bottom of the thread. The tap is made to correspond with this, and is also used to tap the lock-nut. The barrel was graduated on a mandrel in the lathe.

using a 50-tooth gear, and marking at every second tooth, making 25 divisions. A straight line is drawn on the end of the frame at *D*. The screw is screwed into the frame until the barrel is within $\frac{1}{8}$ inch from the angle of the frame, bringing the division marked 0.25 exactly on the line. The frame can then be graduated accurately by revolving the barrel and scribing at each revolution until $\frac{1}{16}$ is marked off. The clamping device holds the rods firmly in place. We have made four of these calipers,

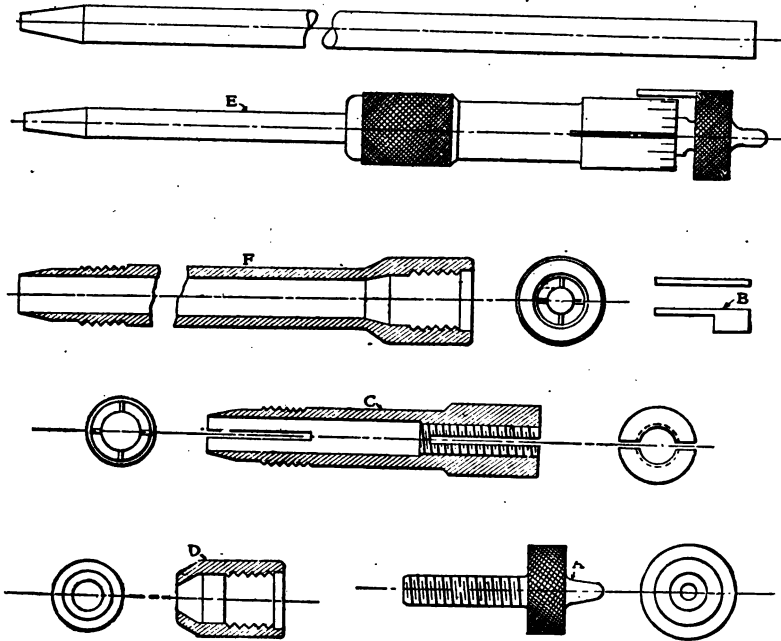


FIG. 158.—Micrometer Gage for Large Work.

which are in daily use and giving satisfaction. The one we have is nickel-plated, which adds considerably to the appearance of the tool. There are six rods allowing measurements from 10 inches to 36 inches.

MICROMETER GAGE

The gage shown in Fig. 158 is designed for large work, and having a graduated head is conveniently used in connection with calipers when making allowance for shrink or press fits.

The screw *A* is 40 threads per inch, and its head is slotted to suit finger *B*, which is made of thin spring steel and sweated in the slot. The barrel *C* is graduated to 25 divisions and slotted, as shown, so as to form a spring fit on screw *A*. The other end of this barrel has four slots, and in connection with knurled nut *D* holds the $\frac{3}{8}$ -inch rod *E* in place. *F* is an extension barrel which is screwed on the lower end of barrel *C*. If a rod, as *E*, is used and it does not pass through both barrels, *C* and *F*, a short $\frac{3}{8}$ -inch rod is placed in *C* to allow *F* to clamp thereon. The nut *D* of course fits the lower end of *F*.

INSIDE GAGE

Having several gun-metal castings to force over gray-iron bodies, we made a gage similar to the one shown in Fig. 159. The casings, Fig. 160, were bored $\frac{1}{2}$ inch taper in 8 or 9 feet, and were large enough in diameter to crawl through. We divided the casing and gray-iron body into a number of equal spaces, as indicated, set our lathe to the required taper, and then calipered the small end of the casing and turned the small end of the body to suit that size. We next calipered the casing at point 2, to find the size that the body should be at the corresponding point, and if the taper body was on the large side, we tapped the handle of the cross-feed till it was right; in this manner we calipered at the different points to keep the work to the required taper, as in the long casing the accuracy of the taper hole bored could not be depended upon. The reason the casing was bored taper was that it could be slipped nearly half way over the body without coming to a bearing.

The body of the gage is made of a piece of $\frac{1}{8}$ -inch brass gas pipe (although it could be made of iron pipe) about 6 inches long. The end *A* is tapped $1\frac{1}{2}$ inches deep with a $\frac{1}{8}$ tap to receive a screw *B*, which has a $\frac{1}{8}$ -inch hole drilled about $\frac{1}{8}$ inch from the tapered end to admit a piece of wire for adjustment. A $\frac{3}{8}$ -inch hole *C* is drilled 3 inches from end *D*, and a stop *E* about $\frac{1}{2}$ inch long is forced down tight in the pipe until it is past hole *C*, then the side of the hole is filed flat and flush with the stop, as shown.

Both ends of the pipe are threaded for a length of $\frac{1}{2}$ inch with $\frac{1}{8}$ -inch pipe thread, and then split on quarters with a hack-saw

to permit them to be tightened up on the extension rod *F*, and the adjustment screw by the brass hexagon nuts, which are drilled out for $\frac{1}{8}$ -inch pipe thread.

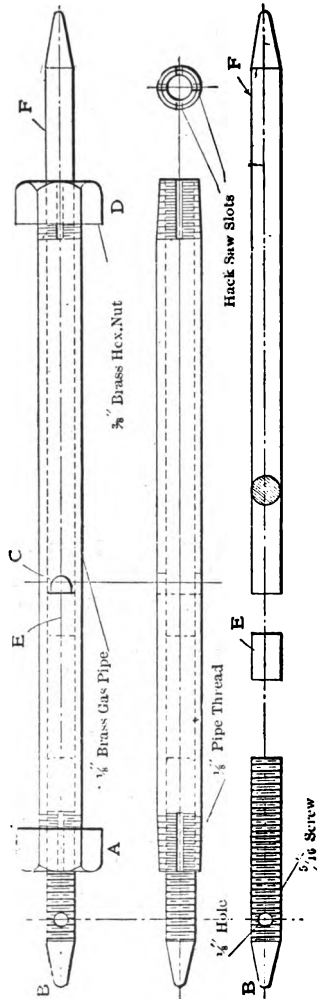


FIG. 159. — Inside Gage.

Extension rods *F* are made of $\frac{1}{4}$ -inch steel wire, and should vary in length by about $\frac{1}{4}$ inch. In calipering a hole, you insert a rod in the end of the pipe till it reaches stop *E*, and clamp it by its nut, then adjust screw *B* to get the required size, and clamp it also.

INSIDE MICROMETER

The Towndrow micrometer, Fig. 161, measures from .995 to 4 inches, in thousandths, and consists of a head cross-wise to receive a split and internally thread bushing, which is clamped

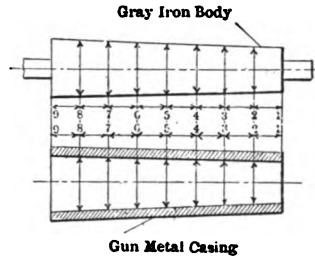


FIG. 160

by a small eyebolt threaded to fit the end of the knurled handle. The bushing thread is 40 per inch, and one end is provided with twenty-five graduations, so that with one measuring point screwed in tight, the other may be turned by a small knurled spanner to give the desired setting. The measuring points are

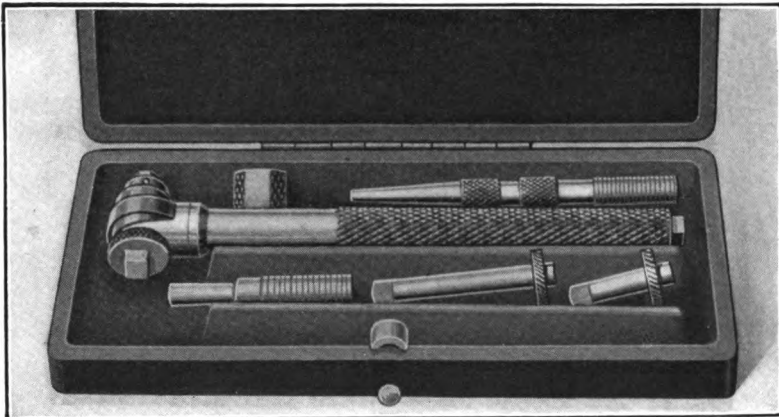


FIG. 161. — Inside Micrometer and Attachments.

of such length that with the removable one screwed up against the one that is fixed, an even inch setting results; the adjustable point is then unscrewed to give intermediate setting by thousandths. Provision is made in the instrument for adjusting for wear on the points.

AN INSIDE MICROMETER CALIPER

We have had occasion to bore holes in the lathe, which was necessary in order to make as straight and as near a certain size as possible; and, as is often the case, in some of the shops the supply of reamers was limited, and it required some very careful feeling with ordinary spring calipers to reach the desired result. Now there was not then on the market an inside micrometer caliper which would caliper less than 2 inches, and at the time we made the one about to be described, the one which we could get our hands on would not caliper less than $2\frac{1}{2}$ inches. Some one probably suggests, "Why not use solid gages?" Well, solid gages are all right for some work, but the supply of them, like those of the reamers, was limited, and they were not limit-gages either. This caliper is not intended at a measuring instrument,

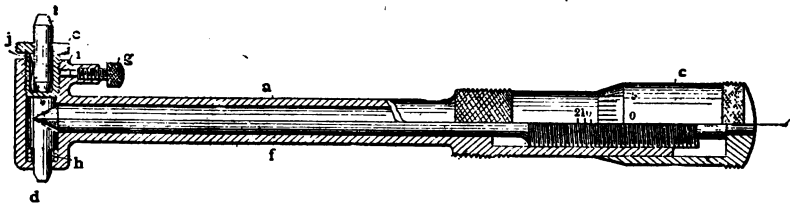


FIG. 162. — Special Inside Micrometer.

but is to be used, in connection with outside micrometer caliper, for setting for the required size, either above or below, and may be readily adjusted or detected in thousandths of an inch.

It consists of frame *a*, Fig. 162, the spindle *b*, micrometer sleeve *c*, movable contact piece *f*, set-screw *g*, friction *i*, and friction-spring *j*. All parts are steel except friction piece *i*, which is brass; and all wearing surfaces are hardened. The frame *a* is in one piece, drilled, reamed, and tapped to receive the spindle *b*. The straight portion of the spindle is made of nice working fit in the frame by grinding (after it is hardened) for about $1\frac{1}{2}$ inches from the point. In fact, it is necessary to the proper working of the caliper and the fits, for all the moving parts to be made in this manner.

The sleeve *c* is made a tight fit on the end of *b*, and has twenty-five divisions. The spindle is threaded twenty-four per inch, and the angle of its point is such that one revolution causes the

contact piece *b* to move twenty-five thousandths of an inch, and has a range of one-tenth inch.

The contact piece *d* is first turned to fit in its proper place, but the body of it is made considerably longer than necessary. A point reamer, the same shape and size as the point and unthreaded portion of the spindle, is then inserted, and a conical hole made in the piece of such a depth that the point of the reamer just comes through. It is then cut in two, leaving a half conical face on *d* to form a seat for the point of the spindle *b*. This method avoids the necessity of making a perpendicular key-seat in *d*, and a pin or key in the frame to keep the piece from turning, which would be required if the angular face of *d* were made flat. The movement of *d* will be uniform if the point of the spindle is not forced upon it to a greater depth than that to which the conical hole was reamed.

SECTION VI

HIGHT AND VERNIER GAGES AND ATTACHMENTS; THEIR CONSTRUCTION, VALUE, AND USE.

ATTACHMENTS FOR THE VERNIER AND DIAL TEST INDICATOR

AMONG the valuable small tools in general use in machine shops and manufacturing machinery plants, none is higher up

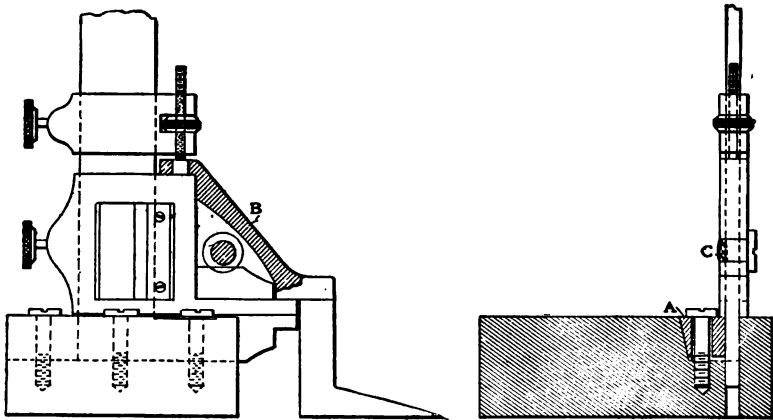


FIG. 163. — Vernier Attachments.

than the vernier gage. Very often such tools are made still more valuable by the aid of some little attachment. Fig. 163 shows the vernier transformed into a hight gage. The base is made of gray iron, having a slot cut near one side so the tool can be brought nearer to the work when locating a jig button. Having set the sliding jaw of the vernier to zero, place it in the block or stand and clamp it securely by the jig *A*; place the scribing and hight gage attachment *B* on the sliding jaw and fasten with screw *C*. Setting the attachment down even with the block or surface plate enables one to work from the bottom of the surface plate when locating jig buttons, laying out work, scribing lines, etc.

Having the buttons located on the plate or jig, the indicator is now wanted for truing up for boring the holes. In many

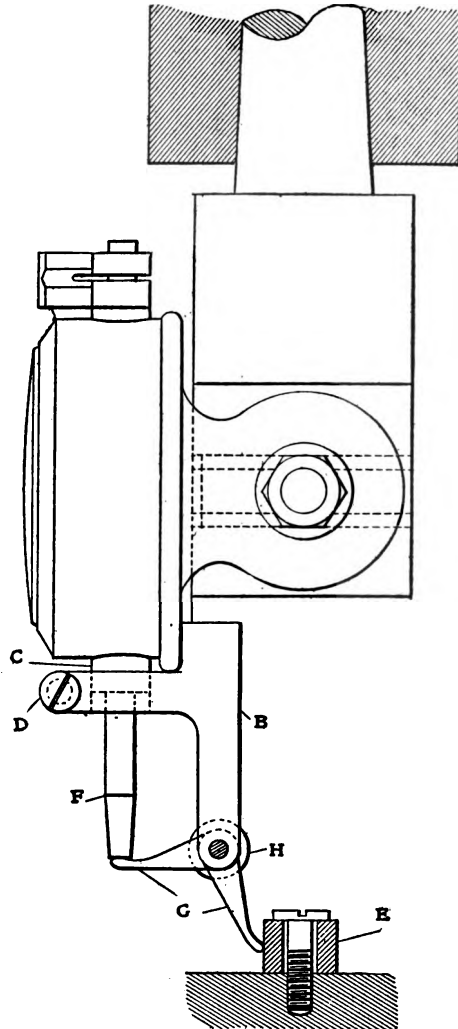


FIG. 164. — Dial Test Indicator Attachment.

instances the lathe is not available or suitable to do the work; therefore we must use the milling machine or the drill press. In Figs. 164 and 165 a dial test indicator (Brown & Sharpe) is

shown fastened to a shank fitting to a drill-press spindle. A T-slot is cut for the bolt *A* for clamping; this slot also permits adjustment of the indicator. The attachment *B* is now clamped to the hub *C* by screws *D*, and the arms *G* are adjusted, one to the button *E* and the other to the rod *F*. The joint *H* is shown in cross-section in the bottom view and requires no further description or explanation. When using this device in the drill-press or milling machine, the spindle of course must be turned by hand, and the reading of the dial noted while turning slowly and adjusting the work until true.

This device can also be used in the lathe by using a shank fitting the tail stock, the arms *G* being adjusted to suit the button

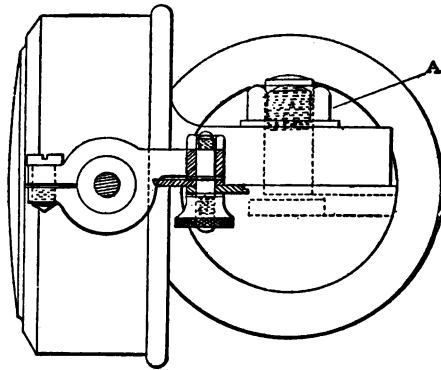


FIG. 165. — Dial Test Indicator.

or the bored hole, as the case may be. As the work in this case revolves, its truth is readily ascertained.

PARALLEL VERNIER GAGE

The cut, Fig. 166, shows a parallel vernier gage that has proven to be very handy in measuring when lapping and milling snap gages; it can also be used as a small height gage to measure the distance from a shoulder to the base on a planer or milling machine job. After a snap gage has been ground or lapped in a machine to within, say, .0005 inch, it must be hand-lapped, for a slight tipping to one side or the other is bound to occur in the machine, and as a consequence the surface becomes belly-shaped. The tool illustrated is used in connection with the lapping in order to get perfectly straight and parallel surfaces. It has a rise of

$\frac{1}{2}$ inch in its length from .600 to 1.100 inch, and it may be used for any greater height by fastening half-inch blocks on top of the slide with screws. If such blocks are used they must be hardened, ground and lapped true. The slide *B* is made of tool steel and is composed of two pieces. The top plate is hardened and ground and soldered on. Four small screws hold gibs in position and provide adjustment; the tapered knurled screw *C* serves to lock the top slide at any point on the base *A* by lifting the binder *D*, which is slotted on the under side to fit the dovetail on *A*. The flat spring *E* is placed in the top of the hole in *B* in order to push the bushing down clear of the dovetail, *A*, so that the slide *B* may move freely when released. A $\frac{3}{32}$ -inch hardened sheet

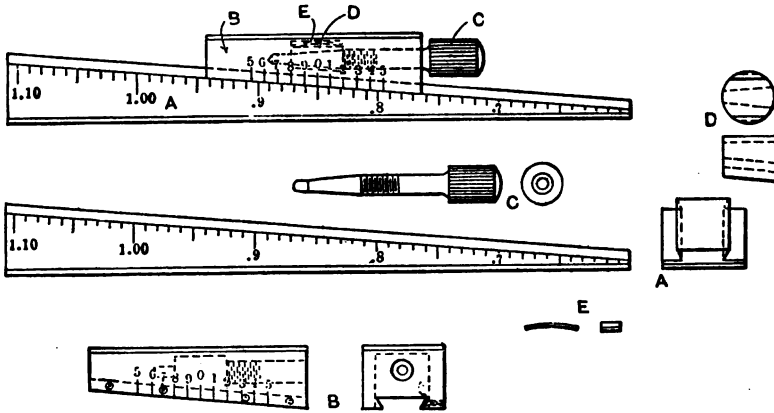


FIG. 166. — Parallel Vernier Gage.

steel plate is also soldered on to the bottom of the base *A*, thus forming hardened working surfaces on top and bottom. The tool is ground square and parallel all over, and the top and bottom are lapped, care being taken to have the sliding parts scraped straight in order that the measurements will register correctly for all settings.

When it is finished and assembled, the graduations should be marked. This can only be done by hand. Mark the slide *B* in the center with a zero line and locate it at .600, .700, .800, etc., positions on the base by using a micrometer, and mark each position with a line and the proper figures, as shown in the cut. Then divide each space into ten equal parts. To make the vernier the top scale must be laid off so that ten spaces cover the

distance of eleven on the lower scale, $5\frac{1}{2}$ of the divisions on the lower scale being on each side of the zero line when set, as shown in the cut. The divisions on the vernier should be numbered from 1 to 5 on the right-hand side, and from 5 to 9 on the left-hand side of the zero mark. It will thus read in tenths, hundredths, and thousandths. The graduation of the instrument is similar to that of vernier calipers, and is read in the same way; but it is much plainer on account of the pieces being wider. In the position shown the gage reads .850 inch. If one or more thousandths is wanted, move the slide along until 1, 2, 3, etc., meet the corresponding lines on the bottom scale.

Under no circumstances should this tool be hardened, as it will warp so that it is impossible to lap it straight. This is the reason that the hardened steel plates are soldered on top and bottom, so as to give it a hard surface on the principal wearing parts.

HIGHT GAGE FOR TESTING AND LAYING OUT FINE WORK

In Fig. 167 is shown a tool constructed for laying out and testing fine work. It has a range by thousandths, from zero up to 5 inches, the adjustments being accomplished by the plug fitting the five bushed holes in the beam slide, and the micrometer screw at *o*. The holes serve to divide accurately the 5 inches into equal steps, while the screw and micrometer nut *p* give the fractions of an inch in thousandths. The beam *q* fits into base-block *e*, and is secured there by tapered dowels. An easy way to obtain a rectangular hole in such a block is to mill a slot of the desired width, starting at the rear end of the block, and then fit a piece of steel, as shown at *s* in the rear part of the slot, this piece being secured in place with dowels. Also through the forward part of a block there is a slot which allows the measuring or scribing jaw *t* to come flush with the bottom of the base; this jaw, as well as the base block, is hardened and accurately lapped. The knurled head-screw *u* bears against a flat spring which always holds the slide in position when the hardened and lapped plug *v* is withdrawn. The micrometer screw, which has 40 threads per inch, is splined and slides on a key which is inserted in the slide. Against this key the tapered and knurled screw *w* bears, thus locking the micrometer screw at any point. One of the essential points, when building a tool of this description, is not to have

the bushing holes in perpendicular alignment; in other words, they do not want to be located so that the plug *v* can be entered into No. 3 holes in the slide, and yet go in a No. 1 or No. 2 hole in the beam.

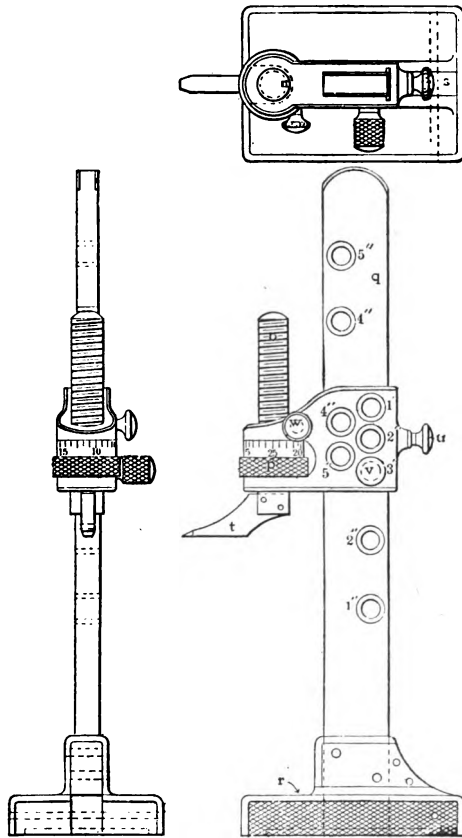


FIG. 167.— Tool for Laying Out Work.

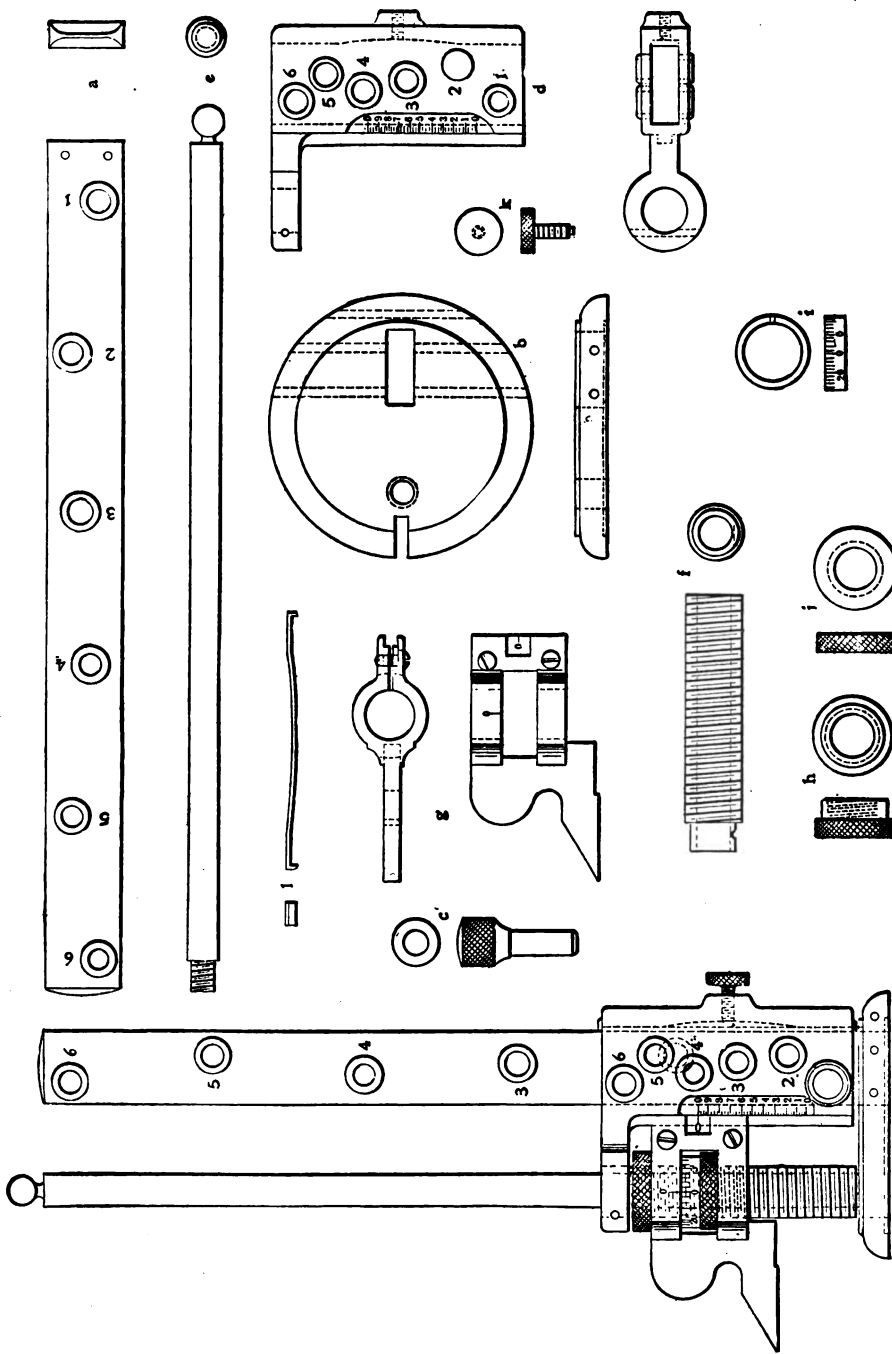
The rectangular hole through the slide is formed in the same way as the hole through the base block—that is, by milling a slot and inserting a piece of steel at the open end. The micrometer nut *p* is made in two parts; the knurled and graduated ring being a press fit on a hardened and lapped nut. The advantage of this construction is that it allows the tool to be correctly adjusted without much trouble.

A SIX-INCH HIGHT GAGE

The following description pertains to the hight gage constructed as shown complete in Fig. 168, and in detail in Fig. 169. It has a range by thousandths, from zero to 6 inches, is rigid and accurate, and can be quickly set to exact position by inserting a plug, as shown. The set of six independent holes through both slide and beam are fitted with hardened steel bushings, ground and lapped to fit the plug, which locates the various inch settings.

The beam *a*,—which forms the main body of the instrument, is made of tool steel, and one end is fitted to base *b*, which is held in position by two straight pins. In a gage of this design we must not have the bushing holes in perpendicular alignment so that the plug *c* will enter any other hole than the corresponding hole in slide *d*. The holes in the beam are not drilled till after the gage is assembled. The base block is made of mild steel and case-hardened, and in the edge of the block there is a slot which allows the scribing jaw to come flush with the bottom of the base. A hole is bored and tapped to fit the rod *e*, and this hole must be parallel with the hole for the beam. An easy way to make the rectangular hole is to mill a slot of the desired width for a driving fit for the beam, starting at the rear of the block, and then fit a piece of soft steel in the rear of the slot. This piece is riveted securely in place with a soft steel wire, and finished on the outside to conform to the base, which is now as good as solid. The bottom of the block is turned out in the center to within $\frac{1}{4}$ inch of the edge.

The screw *t* is $\frac{1}{2}$ U. S. standard and cut twenty threads per inch; a $\frac{1}{16}$ -inch hole is bored through the center to receive rod *e* and is recessed in the middle to give it a free sliding fit. The upper end of the screw is turned to a driving fit in the slide *d*, and secured in position with a pin. The top of the thread is turned off .01 inch to allow the scribe to slide freely on the screw. The nut *h* is used for lowering and raising the slide, but instead of having the graduations placed directly upon it, the micrometer nut is made in two parts; the knurled and lapped nut fits the graduated ring *i*, being a press fit. The advantage of this construction is that it allows the tool to be correctly adjusted without much trouble. The ring *i* is graduated with fifty divisions, each



Figs. 168 and 169. — A Six-inch Height Gage.

equaling a movement of the scriber of .001 inch. This ring may be turned by means of a small spanner wrench so as to bring the zero line into correct position to compensate for wear. A knurled locking nut is also provided for holding the scriber in any fixed position.

The scriber is of tool steel, hardened and lapped to a finished surface; it should be ground at an angle on top when the edges are worn. The rear end is slotted to fit the rib of the slide, and provided with two screws to compensate for wear. On the scriber there are two zero marks, which show at a glance the measurements being taken. The slide is also of tool steel, and at the top a hole is bored to fit the end of the screw, but not till the rectangular opening is milled to assure its being parallel. The rectangular opening through the slide is made in the same way as that through the base by milling a slot and riveting in a piece of steel at the open end. At the front is a rib for the scriber to slide on, and one side is milled at an angle and has graduations of .025 inch for a distance of 1 inch.

The knurled head screw *k* bears against a flat spring, which always holds the slide in position when the plug *c* is withdrawn. When the tool is assembled, the scriber is set to zero with the standard length gages 1, 2, 3 inch, etc., and fastened with the knurled head-screw. The holes are now drilled and reamed through slide and beam at the same setting; the same operation is performed with lapping after the bushings are driven in.

SECTION VII

TRY-SQUARES, KNIFE-EDGE SQUARES, COMBINATION SQUARES, STRAIGHT-EDGE TEST AND SIZING BLOCKS, TOGETHER WITH METHODS FOR THEIR CONSTRUCTION, TESTING, USE AND ADAPTATION.

SQUARES AND SQUARES

THERE is no doubt whatever that the commercial hardened squares are used in many shops wherein their blades are nearer straight than anything else ever seen there. In such shops these squares are for all practical purposes straight and true and square. To refine them still more, and to charge the higher price that would thereby be made necessary, would obviously be a mistake for such shops. It is clear enough, however, that there is a class of work requiring greater refinement; but it by no means follows that it would pay any manufacturer to put the finest and most accurate squares upon the market. In those shops where the finest and most accurate squares are needed, there are always to be found men who, given the proper facilities, can make them. In other words, where the work requiring the use of such squares is done, men must be employed who are capable of making the squares, whether they actually do make them or not; and as most of the work of producing such squares is necessarily done by hand anyway, there is probably little chance of there being ever any great commercial demand for such tools. Therefore every good mechanic should be interested in learning of the proper methods to use, and the mode of procedure to be followed when a square that will be "perfect" is required to be made.

HOW TO PRODUCE A CORRECT SQUARE

It has been claimed that to produce a correct try-square is an extremely difficult job. Oftentimes that opinion has its foundation in the comparison of many commercial squares with

one another. Most likely none of the lot so examined are proper tools as test-squares. In the case of some workmen it is little wonder that their squares are not true and square, from the fact that their association is with files and other tools, to say nothing of the many tumbles they get in their lifetime.

In order to construct a correct square, we must have a standard, by which we may know for a certainty when our square is truly square. Fig. 170 is a standard of this kind, which, with its mate or opposite, determines correctness. *A* is a base with a parallel across its center. At right angles to this parallel piece is a second parallel pivoted to *A* in the center, and held at each end by binding-screws to *A* when in exact position.

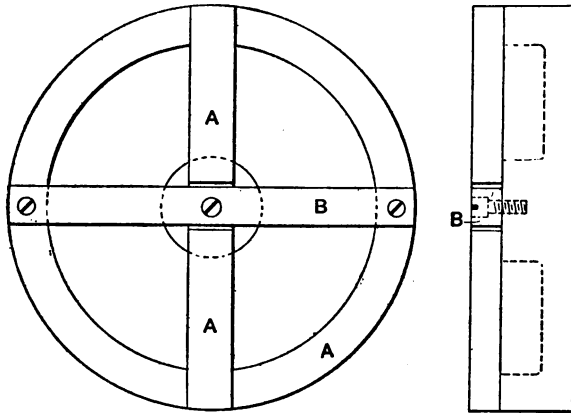


FIG. 170. — Standard for Square Testing.

Special care must be taken that these parallel pieces are made true in every way. Now it is self-evident that when *B* is at right angles with *A*, we have a compound square made up of four right angles. To construct a duplicate to fit we can follow out the removal of discrepancies by eight changes of position if we use the template shown, Fig. 171; or if we make a template with four sides, we can obtain thirty-two trial positions in the construction of an external and internal standard square. Having thus produced an exact square gage, both external and internal, we are provided with a standard of our own, and we are not dependent on that "other fellow's" make for a test-square.

Fig. 172 illustrates a convenient method of constructing a correct square. The base is *D*, and is a plane plate. On this is

mounted the piece *C*, which has been trued by the square, Fig. 170. This fixture is for the purpose of locating the parts in correct position while being fastened together with taper pins. Now if we want a good job we must have a true taper reamer to ream holes to be fitted with good tool steel taper pins that fit

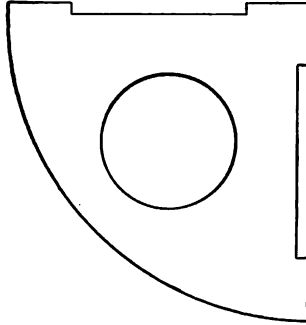


FIG. 171. — Template.

the holes exactly. Press them in — don't drive with a hammer if you want a fine job — while the parts are held rigidly in place on the exact square block, and the result will be that the larger part of all squares thus put together will need no subsequent correction.

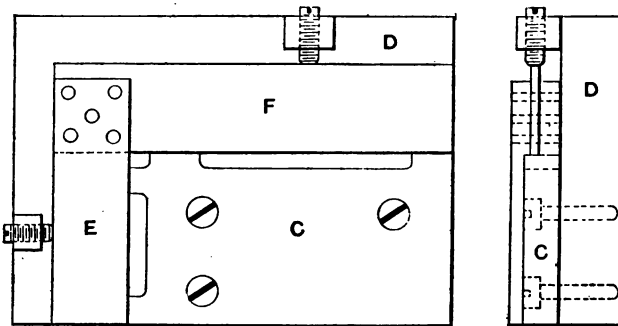


FIG. 172. — Constructing a Square.

First produce good true beams and blades, square and parallel, and then the matter of holding them together rigidly is an easy one if we do the job right, as shown. If we hold the beam and blade together by sweating or solder, we must have a fixture for holding the parts square all the same. If the blade and beam are held in place by taper pins, as illustrated, do not rivet over

the ends to hold the pins in. That will be wholly unnecessary if the pins fit well. When the square is together, grind off the ends of pins neatly with the sides of the beam.

Fig. 173 shows one form of a master square by which all forms of squares may be tested, and in the test the constant correctness of it is manifest. The beam is made of two pieces, *NN*, with blocks *OO* in each end. The whole is carefully finished parallel and square. The blade is also a carefully finished piece, and is mortised into the center of the beam. The openings *VV* serve to test any square, the inside with inside, or its outside, and by

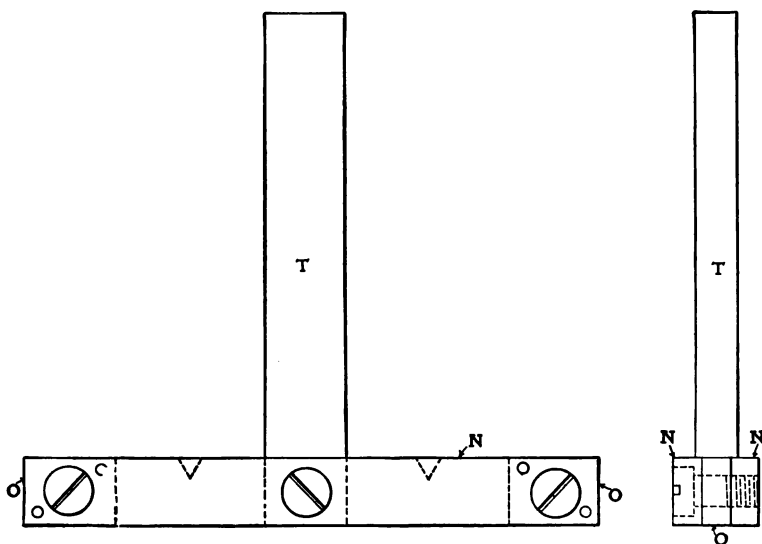


FIG. 173. — Form of Master Square.

the numerous changes which can be made in trial an absolutely perfect square can be produced.

METHOD OF TESTING AND ADJUSTING TRY-SQUARES

There are a number of geometrical methods for laying out the right angles which give theoretically perfect results, but a geometrical method and a practical shop method for producing right angles are two vastly different affairs. Thus, for example, the geometrical conception of line is length without breadth, which is a condition in working mechanics impossible to realize except as the boundary of a solid.

A solid or its equivalent, which will have two boundaries at right angles for testing or adjusting try-squares, is ordinarily produced by a series of tests for inaccuracies with other gages or squares of more or less truth. This may or may not be satisfactory, the results depending entirely on the skill and patience of the workman.

Fig. 174 shows a method for testing and adjusting try-squares which requires nothing besides ordinary tools more than four disks of exactly the same size, but what size is immaterial, except

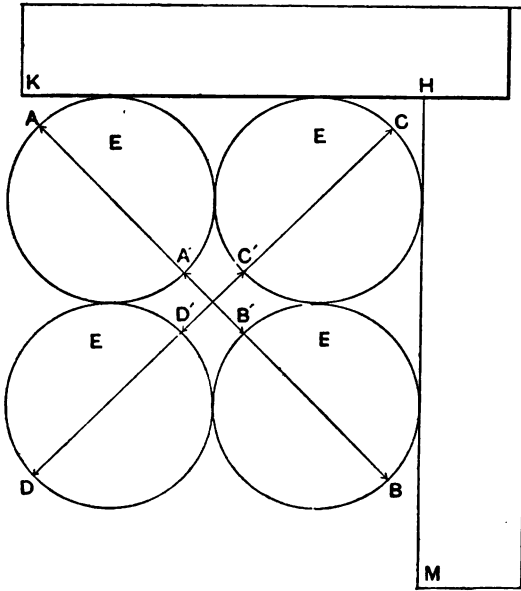


FIG. 174. — Testing a Try-Square.

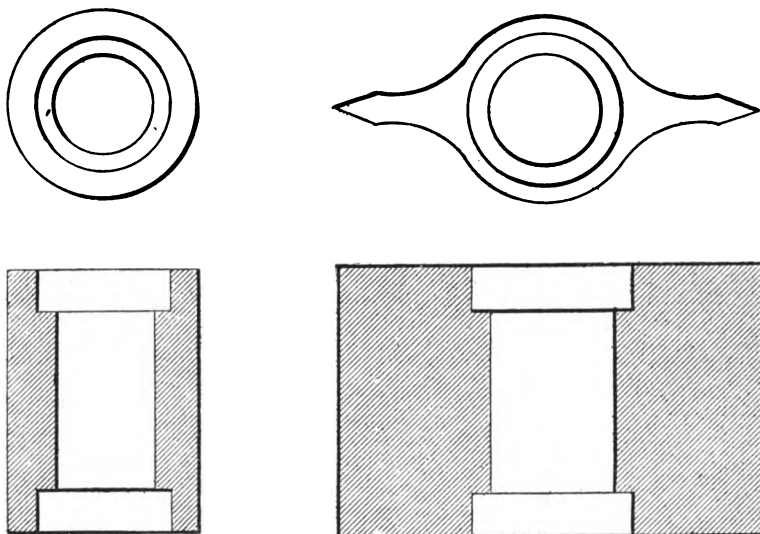
that the disks should, of course, be in proportion to the size of the square to be tested. To obtain four disks of the same size is not difficult, that is within the limits of, say, one ten-thousandth of an inch.

USING TEST-BLOCKS IN PLACE OF A SQUARE

Figs. 175 and 176 illustrate two test-blocks that are used for squares in connection with a surface plate. A small hardened surface plate, finished on both sides, is very useful in making various tests and measurements.

Fig. 175 is simply a hardened cylinder, counterbored at the ends to allow the wheel to run by in grinding the end faces. The cylinder is ground perfectly straight and lapped to any exact size. The ends are then lapped on a surface block. In using this test-block, place both the block and the article to be tested on the surface plate, and test for light, or use the rubbing test.

Fig. 176 is the same as Fig. 175, with the addition of knife straight-edges on opposite sides, which makes of it a double knife-edge square to be used with the surface plate. The advantage of these test-blocks is the comparative ease with which they are



FIGS. 175 and 176. — Test Blocks.

made, and the fact that they can be made accurate in any shop that has a good grinder. If the opposite sides are ground and lapped parallel, and the ends squared at the same time, the sides must be square with the ends, which makes the test-blocks accurate squares.

SIMPLE METHOD FOR TESTING A FLAT SQUARE

Fig. 177 shows a simple and easy way of testing a flat square, such as a carpenter's square, 24 x 16 inches. A good straight-edge is clamped upon a planer platen or a horizontal face-plate, and one edge of the square is backed against it. Instead of drawing a

line along the edge *a*, use two iron plugs of equal diameter. They happened in this case to be two inches thick and three inches long. These plugs were placed on the face-plate as shown. Guiding one edge of the square against the straight-edge, the other edge *a* was brought to bear against the two plugs, and to make sure of their bearing or contact, the square and plugs are moved along together for a short distance, the square pushing the plug. Then the square is backed and turned over and brought to approach the plugs from the other side — see dotted lines — close enough to try the touch at both plugs with tissue paper. If there is a slight difference in the diameters of the plugs, one may put one in place of the other and divide the difference.

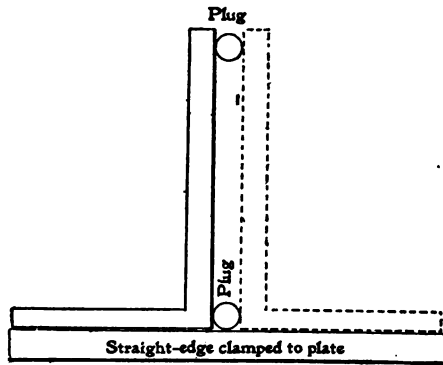


FIG. 177. — Testing a Flat Square.

HOW TO MAKE A KNIFE-EDGE SQUARE

While the purpose of the following is to describe how to make a fine square, and how it should be used, it may not be amiss to say that probably in no other line of manufacture has the interchangeable system been applied for so long a time, or brought to as high a state of perfection, as in the casting of type for printing. This does not mean only that the type of any one foundry will interchange with those of any other. The difficulty of maintaining an absolute interchangeability and its practical necessity will be readily understood if we take a page of this book as an illustration. If the body of each type in a line was just .0001 inch out of square on its lower side, we would have a curved line; if some were out of square at the top, others at the bottom, and still others square, we would have a zigzag line. As each body

type must be firmly bearing against its neighbors when locked in the form, we would have a column of dancing letters that would drive the reader distracted.

Fig. 178 represents a square largely used in making the parts of the molds — which are themselves interchangeable, and are

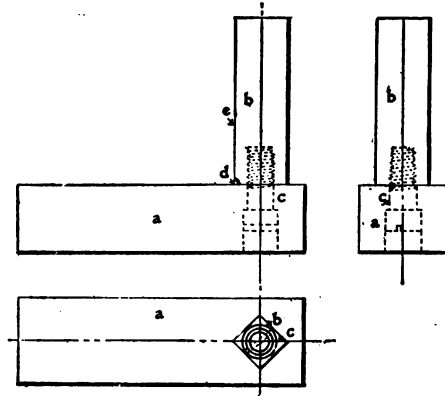


FIG. 178. — Square for Mold Work.

used on automatic machines — its precision block and a lapping plate.

In Fig. 178 the beam *a* and the blade *b* are held together by screws *C* as shown.

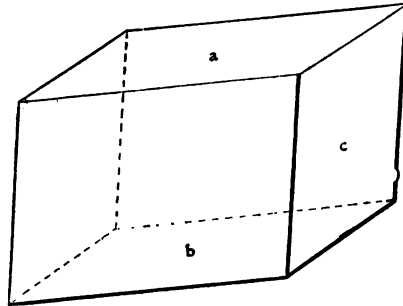


FIG. 179. — Rectangular Prism.

Fig. 179 is a rectangular prism, in which the sides *a* and *b* are lapped parallel and end *c* perpendicular to them. Necessarily, if *c* is square with either side it must be so with the other. All parts should be made from machine steel, deeply case-hardened, and allowed to thoroughly “work” before finishing, but will

require frequent correction as long as used. On account of its extreme sensitiveness the square is worthless without the block with which to test and correct it. The block is corrected by micrometer and its square.

In Fig. 178 the space d is left to catch dust and ravelings of cloth that would interfere if the corner were left sharp.

Figs. 180 and 181 show a lapping plate which consists of a cast-iron plate having a rectangular recess filled with lead or

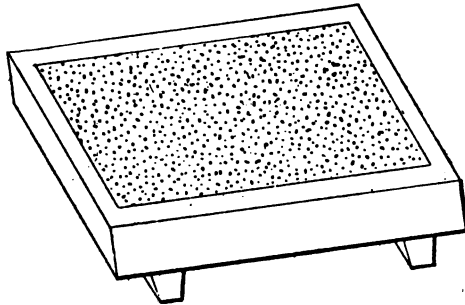


FIG. 180. — Lapping Plate.

babbitt metal, carefully planed and charged with flour of emery, by means of cast-iron stick and water. There should be a pair of these — for roughing and finishing — and care must be taken to so use them that the wear is about uniform. When the lead is poured the casting should first be made very hot to contract with the lead in cooling.

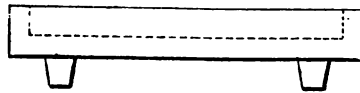


FIG. 181. — Lapping Plate.

In making the square the beam and blade are hardened, ground and lapped; the beam on one side, the blade on two adjoining sides, and the screw end.

As it is quite impossible to lap the end of the blade perfectly square, the corner e is honed after assembling until it is square, and afterwards corrected in the same manner as needed. The square should never be taken apart for that purpose.

The length of the beam is usually about $2\frac{1}{4}$ inches, and the blade $1\frac{1}{4}$ inches. The block is slightly larger than the square. The lapping plate is about 10 x 14 inches.

With practice an error of .0001 inch can be easily detected, and in the work for which they are used the limit of error is slightly less.

KNIFE-EDGE SQUARE WITH HANDLE

It must be admitted that a square of such fineness as the knife-edge, if used much, will naturally spring out of truth from the heat of the hand and fingers while holding it. We have used the square shown in Fig. 182, with a wooden handle fastened to the beam of it. The handle is also convenient for picking up

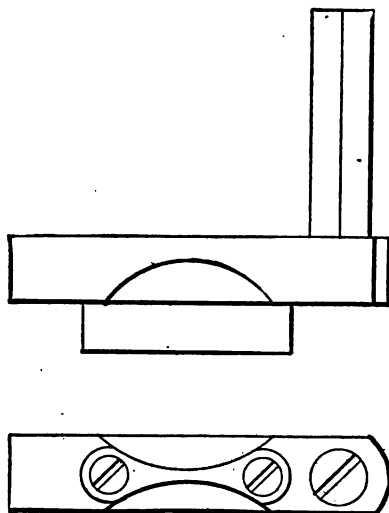


FIG. 182. — Knife-Edge Square.

the square. The space left for dust at the vertex of Fig. 178 is a drawback sometimes, but for certain work this is the most valuable part of the square. The square shown in Fig. 182 was made of tool steel, hardened and drawn to a light straw.

A SET OF KNIFE-EDGE TOOLS

Fig. 183 shows a knife-edge bevel; at the top is shown the stock. It is one of the handiest tools for use on the surface grinder. It is made of tool steel, hardened and ground all over.

Figs. 184 and 185 show two knife-edge straight-edges *A* and *B*; Fig. 186 is a test-bar, Fig. 187 a knife-edge square, and Fig. 188 a test-block. Considerable trouble will be experienced in

keeping tools like these true, especially in winter. The warmth of the hand will throw them out of truth. This can be overcome by putting in the fiber or hard rubber, as shown by the dotted lines. These tools should be kept in a box with a little oily waste to prevent rust.

A KNIFE-EDGE STRAIGHT-EDGE

Fig. 189 shows not a lethal weapon, but a knife-edge straight-edge. It was made by grinding and lapping an old flat-ground English razor. It remains true longer than many bought straight-edges, and this quality may be attributed to the long years of

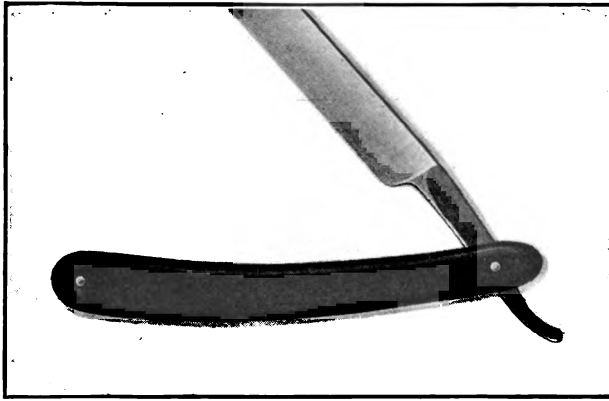


FIG. 189. — Knife-Edge Straight Edge.

seasoning it underwent while in use as a razor, previous to its regeneration as an instrument of precision.

The handle protects the edge very thoroughly. One of the washers has been left off the little pivot for the blade, so that the handle may be easily removed should it be necessary.

USES OF THE COMBINATION SQUARE

No doubt we all have seen at times our ideas and inventions improved upon, or used to better advantage than we have used them. So the sketches, Figs. 190, 191, and 192 may convey some new ideas in conjunction with the combination square. We do think it might be of advantage to the makers to offer an extra

base for a slight advance in cost. Fig. 190 shows the square used as a hight gage which will go into places that surface gage cannot. Fig. 191 shows it used as an outside caliper. Fig. 192 shows how

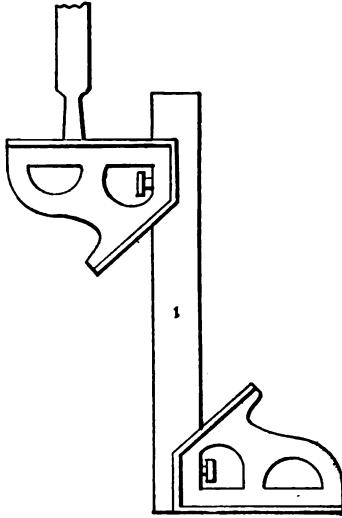


FIG. 190. — Use of Combination Square.

odd shapes may be calipered on the outside. Edward Etler, a planer hand at the R. K. Le Blond shops, Cincinnati, Ohio, is responsible for these ingenious ideas.

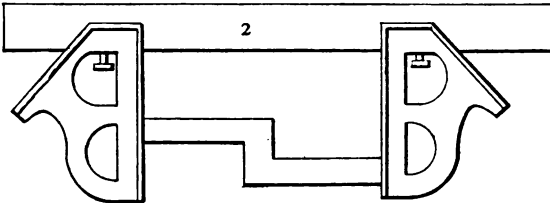


FIG. 191. — Use of Combination Square.

ADJUSTABLE SIZING BLOCK

Fig. 193 shows a sizing block which was made for use on the planer. The body of the tool *A* is made of machine steel. After the slot is cut in it the machine steel piece *B* with the foot *C* is fitted to it, a nice snug sliding fit. The hole *D* is then drilled and tapped $\frac{1}{2}$ inch, twenty threads, and is so located that only

about one fourth the circumference of the tap cuts into *B*. *B* is then removed and a $\frac{1}{4}$ -inch rose bit is run down into the hole in

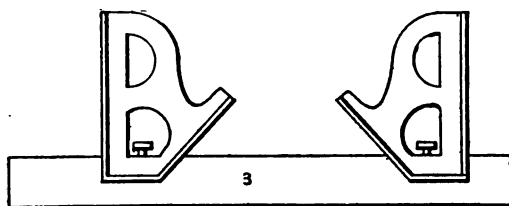
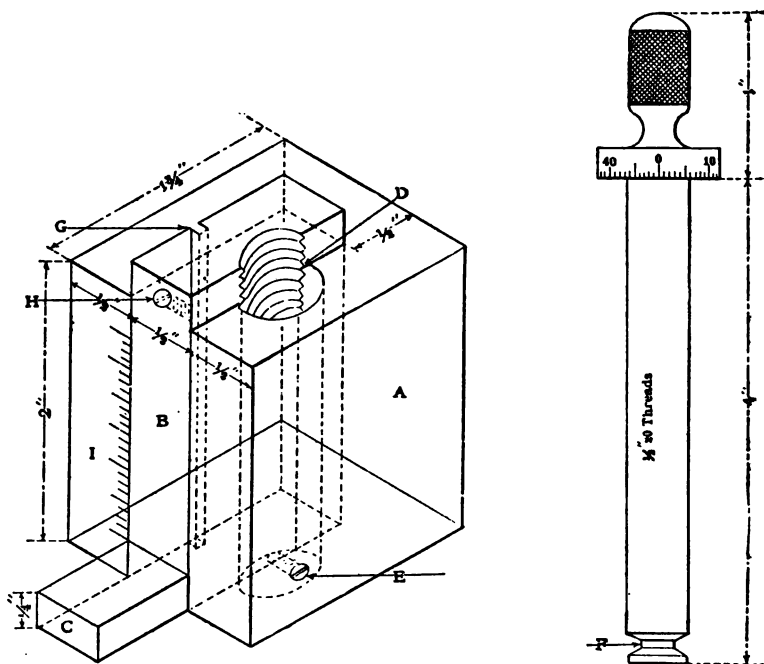


FIG. 192. — Use of Combination Square.

A, cutting the threads away. The steel screw, Fig. 194, $\frac{1}{2}$ inch in diameter, twenty threads, is then made. At its lower end is the V-groove *F*, into which the screw *E* engages when the tool



FIGS. 193 and 194. — Sizing Block.

is assembled. A groove *G* is milled in the piece *B*, so that the screw *H* may hold *B* and *A*, and allow it to slide up and down freely without binding on the screw, Fig. 194. An indexing

point is fastened to the top of *A*, and reaches up to the divided collar on Fig. 194. The collar is divided into fifty parts, and as the screw is twenty threads, each division equals .001 inch. The face *I* of body *A* is graduated to twentieths and tenths, which may be easily done if left till the last by using the tool itself for spacing. The foot *C* and the top of the sliding block *B* are used for sizing. The capacity of the tool as shown is from $\frac{1}{4}$ to $3\frac{1}{4}$ inches by thousandths.

THE MAKING OF A REAL SQUARE

There are classes of work for which the commercial square that can be purchased in the tool store or of the makers is not nearly good enough; though of course this is not saying that the commercial article is not good enough for the vast majority of work, and also a very good value for the price asked for it, as good indeed as could reasonably be expected. We all know that all our tools and machinery lack more or less of being absolute perfection, and it is a part of the business to know when a thing is good enough for the purpose it is designed for; or as good as people can be induced to pay us for making it.

Other things being equal, it is perhaps generally true that the harder the materials we work with, the more readily errors in our work manifest themselves. The carpenter's square does not need to be nearly so accurate as that of the machinist, partly because if the end is not cut off precisely square the relatively soft material will yield sufficiently when it is forced to place, to make the joint good enough, and something like the relative difference between the harder and the softer materials is seen when we compare unhardened metals with hardened and ground or lapped steel. For such work the store square even of the very best make is sometimes not nearly fine enough, and it may be useful if we describe the methods that have been followed in making squares that are much more refined and which in fact enable us to produce work which is so nearly square as to make it possible to detect error in it by the most refined tests that can be applied.

The best manufactured square, as shown in Fig. 195, consists of a stock *a*, which is made of three hardened pieces, the central portion *b* (corresponding in thickness to the blade) and the two

outside pieces dd ; these three pieces are hardened and finished true all over, sweat or soft-soldered together, and finally riveted with two or more rivets clear through.

To better resist hard usage and prevent breakage, the blade is hardened only on the edges, as shown by the dotted lines. The blade is fastened into the stock by sweating or soft-soldering, and by moderately heating it may easily be removed and reset in case of wear or accident.

In use, and where the work is not too large, such a square is put upon the work and held up to a strong light for inspection.

Another method used, especially with large work, is to apply narrow strips of paper at each of the blade ends for contact, these

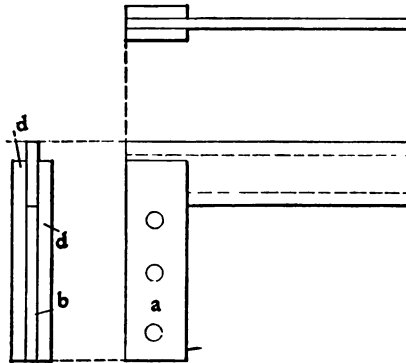


FIG. 195. — Making a Real Square.

strips being manipulated by the finger, and when they are pinched or held alike, one can be pretty sure the work is very nearly like the square. The paper strips in connection with the micrometer calipers have one advantage over the eye inspection, in that they not only tell us when the work is out, but very nearly how much, which is really what we want to know. In the "American Machinist," some years ago, was illustrated a square invented by G. A. Bates, in which the blade is pivoted on a projection of the stock, and by a system of levers and a scale is made to indicate the truth or untruth of whatever it is applied to, and which way and how much it may be out. Just why this square has not come into use would be hard to say; though it is probable that, like a great many other things mechanical, it was born too soon.

For very fine work, such as gages, instruments and some

kinds of tools, no square with a flat-edge blade will answer the purpose, for the simple reason that the contact between the work and edge of the blade is too broad and will shut out light when they are not really together at all; and the paper strip method would not answer, because the paper is too uneven in thickness and too rough to give the required accuracy. And besides, most work of that character would be too small to handle in that way; so what are called knife-edge squares are used. For some reason, probably because of their necessarily high cost, this class of square is not listed in any maker's catalogue. The few that are in use have mostly been made by the workmen using them.

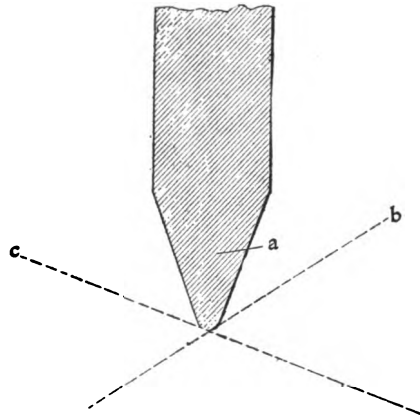


FIG. 196. — Making a Real Square.

A hardened steel square of a size usually below the 3-inch, such as was described above, is sometimes used as a starter. The blade is heated and taken out of the stock, and this latter is then refinished on its two edges by grinding and lapping until they are flat and as near perfectly parallel to each other as it is possible to get them, by the use of the micrometer caliper or other gaging device. The blade is now taken in hand and its inside, and sometimes its outside, edge beveled off, as shown at *a* in Fig. 196 (enlarged).

The sharp edge is slightly rounded, like a knife-edge straight-edge so it will stand wear a little better. It is now put in place in the stock, care being taken to have the contact surface nicely tinned and all the surplus solder removed. They are set by trying

on a block, preferably hardened, and which is as near square as it is possible to make it, and temporarily held and clamped on the sides of the stock and over the blade. It is then heated to melt the solder and to secure the blade. On account of the heating necessary to melt the solder and the disturbing influence of contraction and expansion, it will be found very difficult to get the blade set even approximately right, and sometimes as

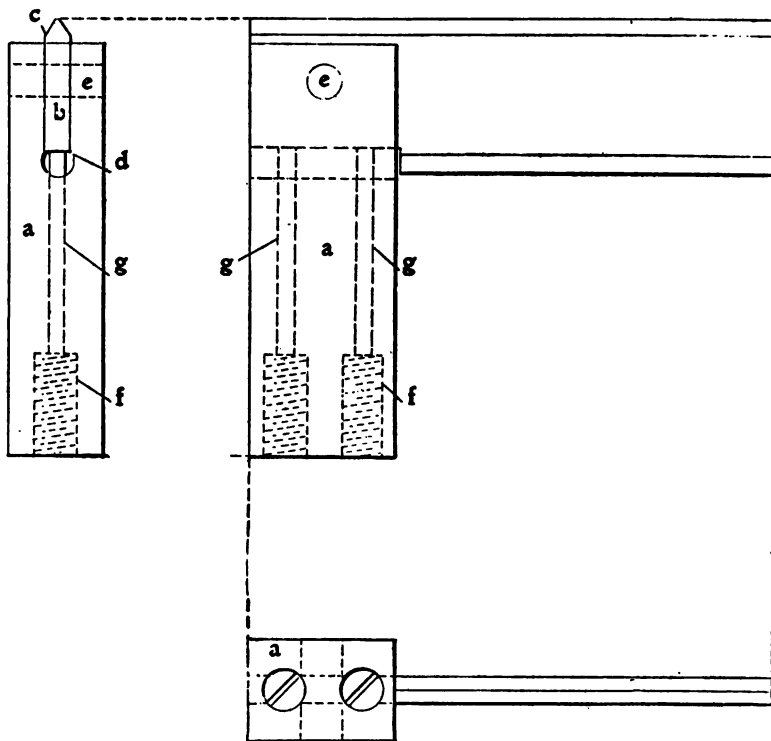


FIG. 197. — Making a Real Square.

many as four and five trials are necessary. After this the hand is resorted to in order to get it to the required degree of accuracy.

This difficulty in setting the blade has led to several designs in which the blade is held by pin, screw, or keys, doing away entirely with the necessity for heating. One of this variety, which has given entire satisfaction, is shown in Fig. 197.

Every piece in this tool is hardened, even the screws and pins, and it is found that by so doing they "stay put" for a longer time.

The stock *a*, in Fig. 197, is made of a single piece. The slot which holds the blade ends in a round hole *d*, which serves the double purpose of preventing fire-cracks during hardening, and makes a clearance that is useful while lapping out the slot; which must be done so that it closely and without shake fits the blade which has previously been finished. The stock and blade are pivoted together and free to turn on pin *e*, which need not be fitted with any great accuracy.

In the stock are the two screws *f*, and above them the two loose drill-rod pins *g*, all shown by dotted lines.

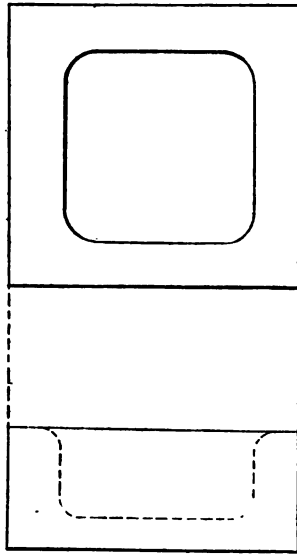


FIG. 198. — Square Setting Block.

It will be seen that with this construction the blade may be quickly and accurately set, and firmly, and that when the fine edge of the blade becomes worn, it is a very small job to remove and reset it, that is, if we have a block which is square to set to. Such a block is prepared in the following manner:

It should be of steel, either tool steel hardened through, or machinery steel, case-hardened, and of a form shown in Fig. 198, the sides or edges being slightly longer than the square blade.

From one side the center is milled out, merely to make it lighter and more convenient to handle. After hardening it should

be immediately drawn slightly to take out the strains, preferably in hot sand or oil, and as slowly as possible.

It is then ground on a grinding machine on its flat side and four edges, and all these are made as near square to each other as it is possible to get them by grinding. Then, unless the job is urgent, the block should be laid away, the longer the better, but at least a week, to allow it to settle before beginning to finish by lapping.

It will of course be understood that for work of this character the lap must be very true and flat to be of any use whatever. A good lap for this purpose, and for general tool and gage work, is prepared as follows: It should be about 15 x 24 inches, of cast-iron, with the cast face downwards. In form it is a flat plate 2 inches thick, ribbed on the under side with ribs $\frac{3}{4}$ inches thick and 4 inches deep, arranged like the ribs on the Brown & Sharpe surface plates, and bearing its weight on three points to avoid springing.

In order to get a flat plate and do anything like fine work, it is necessary to have three of these plates, all alike. They should be planed smooth all around the four edges and on top, which should also have grooves planed in it running lengthwise only, about $\frac{1}{4}$ to $\frac{5}{8}$ inch apart, and of a shape that would be made by a 60-degree thread tool with the point slightly rounded.

These grooves should be about $\frac{3}{8}$ inch wide at the top, and planed in at one cut, so that they may be slightly rough on the edges, and so hold the emery better.

After planing, put one of them face up on a bench or box, where it can be got at from two opposite sides; turn another plate on this one, faces together, and with benzine and No. 100 emery between, and with two good strong laborers to operate, proceed to grind or lap them together, keeping the surface wet with benzine. When they begin to bear all over, lay one aside and take a new fresh plate; next lay aside the first plate and lap together the second and third, and proceed in this manner until all are finished. This of course is on the old principle that no three surfaces can all fit each other unless all are true planes.

It is not at all necessary to use red ink or blue as a marking to indicate when they surface each other, as by wiping them clean with benzine and waste, and standing at some ten or fifteen feet — with the plate in a horizontal position between the eye and

the window, it will be very easy to see where the bearing is, as of course there will be no small spots such as there are when two plates are scraped together. The high places will appear to be highly polished, while parts which do not bear will appear dead and like ground glass. The finishing is done with the finest flour emery, and very little of that.

When new they will warp and spring out of shape, and use will wear holes in them, when they are once more put through the lapping process with each other.

For spreading the emery and benzine and charging the plates when in use, it is well to have a cast-iron charging block which is about 5 x 7 inches and four inches thick. On the top and one end are U-shaped handles. The face, which is planed, has semicircular grooves about $\frac{1}{4}$ inch wide and about 1 inch apart, planed both ways to form squares. These grooves form air passages, and prevent sting and hard work. To charge, apply emery to the lap by shaking it in from a box with small holes punched in the cover like a pepper-pot, wet down with benzine from a common oil can; then rub the charging block over the surface from side to side, and gradually working from end to end to cover the whole surface. This block is frequently used also to clean and sharpen the surface of the lap, when it is rubbed over simply with benzine. For finishing such work as we now have in hand, the charging block is rubbed over the lap with benzine only, and the lap is then wiped dry with the waste, wiping from end to end only, and with the grooves, as in this way much less lint will be caught than if we try to wipe across them, or if the grooves are planed both ways.

It is often convenient in doing small work on a lap of this size to have a little emery on one end and the other clean, so that both roughing and finishing may be done without waste of time.

Care should of course be exercised to distribute the wear as evenly as possible. On the start, in lapping the parts of the square, benzine and flour of emery or carborundum are used until the wheel marks are out of the surfaces, while the finishing is done with the lap wiped perfectly dry and clean, the emery bedded into the cast-iron lap being sufficient to cut and polish.

We will now assume that the square, Fig. 197, has been finished, and the blade and stock set as nearly square as by other

means. Referring to Fig. 199, which we will assume is the block, we lap the side *a* perfectly flat and use it as a starter. By lapping we now fit the angle *b* to the square. The testing is done by carefully wiping the square and block surface with the bare hand, or a piece of chamois, applying the square and holding up to the eye before a strong light. When they fit together so closely as to shut out the light the whole length of the blade, we proceed in like manner to angle *c* to *d*.

Now when we get clear around and come to apply the square with angle *e*, we may find, as in the sketch (which is greatly exaggerated for illustration), that there is a considerable space *f* between the outer end of the blade and the block, and this shows that the square is just one fourth of this opening over 90 degrees,

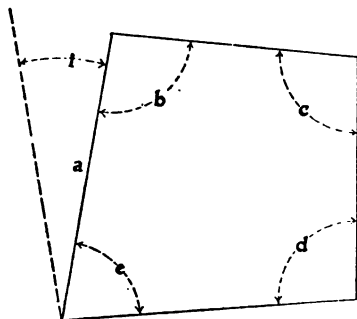


FIG. 199. — Lapped Block.

or, in other words, that the "square's" error is multiplied by four, as shown by this opening on the last or final trial. Should the opening appear at the other end of the blade, it would merely mean that the angle is less than 90 degrees. In either case we reset the blade by one fourth of the opening shown as near as we can estimate, and proceed to fit the angle to the square as before, and repeat this process as many times as it may be necessary to shut out the light on all four corners or angles.

By having the surface clean and dry, and carefully applying the edge of the stock with the blade a little way off, and working it gently to get the air out, we get a good, firm contact, and thus by very gently working it down till the blade barely touches, we can do a very accurate job; for it seems to be very well known that under conditions light may be seen through an opening,

which is only one forty-thousandth part of an inch wide. This will probably be as close to square as we care to go. But there is another method of testing that seems to admit of still greater refinement, and it is as follows: After wiping the block as clean as possible with the bare hand, there will still remain on the surface a thin film of moisture. By gently moving to exclude the air, as before, get the block and stock in close contact, and now bring the blade to bear, and when it does, move it sideways, back and forth by the stock about $\frac{1}{32}$ inch, when upon removal and in a good light it will be seen to have left a slight but distinct mark in the moisture upon the surface of the block. Unless the mark extends the full length of the blade, it shows that while it may have been close enough to close out the light, it did not actually touch all over, and by careful work it may be made to do so. The color of this mark should also be noted as it varies with the pressure between the edge and the flat surface, and is another guide to refinement. It should be uniform in appearance from end to end.

The outside or back of the square is left until the block is completed, when it is tested by standing both block and square on a true flat surface, and proceeding as before, except that the edge is now lapped with a small hand lap to bring it true instead of by moving the screws as before; and of course the block is not lapped, because it has been previously made square.

It is necessary while finishing both edges of the blade, to tilt or roll it on an angle both ways over its slightly rounded edge, making it bear as shown by the dotted lines *c*, Fig. 196. Were this not done, the square might be anything but true, if it were turned ever so slightly at an angle to the work. It is this rolling over and making the edge touch its full length in any position that takes the most time and patience.

A tool of this kind is best made at times and worked in between other jobs, as it will not do to hurry it in the least, and neither the block nor the square can be held in the hand any length of time without being warped or expanded out of shape by the heat of the hand. If these operations be extended over several months or years, at the end of that time the steel will become so settled as to stay in shape fairly well. For some time after the block is started it will be noticed that the corners fall away and the flat surfaces persistently get high in the center.

A quicker but somewhat less accurate way of testing a square is shown at Fig. 200. The piece *a* being made parallel on its two sides, the angle *b* is fitted by scraping or lapping to the square. If the square be now applied to angle *c*, the error, if any, will be multiplied by 2 instead of by 4, as in the other method. This last method has the further disadvantage of depending entirely on the parallelism of the two sides of the test-block.

One rule in squaring work should be: Hold the stock against the shortest side of the work, if there be one, whether that side is to be changed or corrected or not. In this way the angle or error, if there be one, between the work and the blade is extended

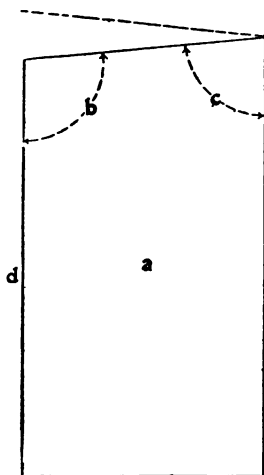


FIG. 200. — Testing a Square.

and much more readily seen than if applied to a short surface, such as the end of the bar.

It will perhaps seem to some good workmen that the square and block above described are carried to an unnecessary degree of refinement for the result that is to be attained.

To illustrate its use, we will consider the making of a snap gage of the style, Fig. 201, composed of a core *a*, having its jaws *b* secured by screws to its two edges. It will of course be understood that the two edges of the core *a* must be parallel to each other, and with the aid of such a square as described, it may be very quickly tested by squaring from one flat side which is previously finished for convenience in grinding. Again, for

making the test piece or end measure, Fig. 202, which is sometimes used in connection with Fig. 201, the two end surfaces must be parallel to each other, and that is most quickly tested by having two sides, as *a b*, finished, though not necessarily square to each other, and squaring from these sides both ways over each end. These illustrations will serve to indicate many uses

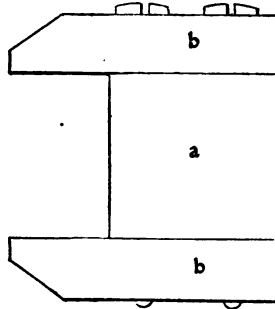


FIG. 201. — Snap Gage.

to which such a tool may be put, and where the time required for testing would be only a small fraction of what would be required for a test by measurement.

A PRECISION SQUARE

The ordinary try-square indicates plainly enough when a piece of work to which it is applied is out of square, provided a good light is obtainable; but when the variation is very slight

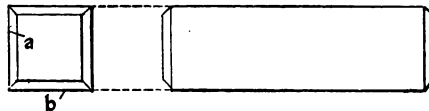


FIG. 202. — End Test Piece.

the light must be a strong one, and the amount of variation must always be estimated; it is not directly indicated.

We present herewith drawings of a square which is much less dependent upon strong light — *i.e.*, a square which does not require that light shall shine directly through between the blade and the work; and one which, while it still leaves the variation from the true right angle to be estimated, very materially assists in estimating correctly.

The square is the invention of G. A. Bates. The blade is pivoted at *A*, Fig. 203, and can move through a small arc. In doing so it moves an indicating lever *B*, which is pivoted at *C*, and connected to the blade at *D*; the result being that when the blade is moved in one direction the lever moves in the opposite direction through a much greater arc, and the variation between the two lines shown — one drawn upon the upper end of the lever, and the other on an adjustable plate attached to the blade — is many times the variation of the work from a true right

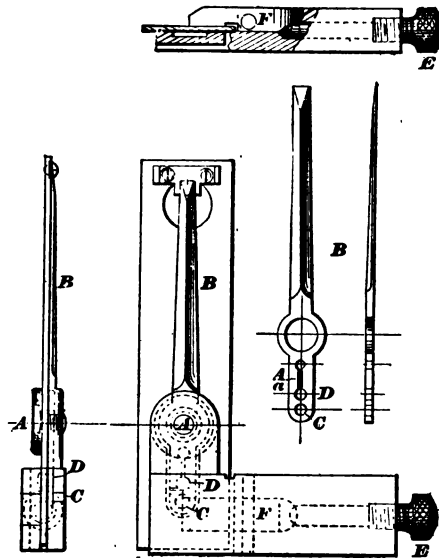


FIG. 203. — Precision Square.

angle, and the slightest variation is very readily seen even when it is difficult, or even impossible, to see between the blade and the work, as is required to be done with the ordinary square. At the same time, when it is desirable to clamp the blade either square with the stock or at a slight angle to it, as is sometimes required, it is readily done by simply turning the knurled screw *E* at the end of the stock, the action upon this screw of the clamping lever *F* being clearly indicated. It is needless perhaps to remark that the clamp has not the slightest tendency to disturb the adjustment of the blade.

To insure that there shall be no lost motion in the connection between blade and indicating lever, the pin which connects them is fixed in the blade, and the hole in the lever is opened, as is shown, and the spring piece *a* is slightly depressed so that it always bears snugly against the pin. The corner between the blade and stock is opened slightly, as shown, so that trouble from dirt collection there is avoided. Fig. 204 shows the stock separately.

In using a sample square, from which our engravings were prepared, Mr. Bates found it to be capable of standing tests of very great refinement, and at Fig. 205 we show a device gotten up for testing and adjusting the square. It is called an adjusting testing block, and is composed of an approximately square block having a groove planed around its four sides, as shown in the

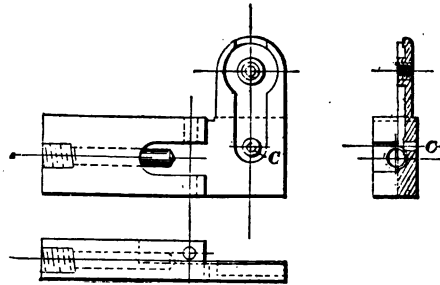


FIG. 204. — Stock of Precision Square.

partial section at the right. Into this groove are fitted four pieces which are pivoted at one end, and at the other end can be adjusted by the screws shown; the larger screw raising the pieces, and the other smaller screws having the opposite tendency, so that by their combined action the piece is readily adjusted and firmly held.

Starting as accurately as possible, two of these pieces, adjacent to each other, were adjusted to fit the square, and the block was then adjusted around to the place of beginning where the error of the square was shown magnified in a way familiar to all mechanics who have ever tried to make a block really square on four sides. This error was then divided and adjusted as nearly as possible, and the process repeated until the square would go all around, showing the least variation. It was then assumed that both testing blocks and square were really square, as in fact they were.

This has been patented by its inventor, who, as a result of his experience with it, calls it his "precision" square. A specimen we have had the privilege of examining is certainly an admirable tool, whether considered as a piece of fine tool making, or in respect to its action when in use.

A REMARKABLE SURFACE GAGE

This surface gage is the original of its kind. It was designed by George Wincock, a man celebrated in the old gun, and early sewing-machine days. It was made in the Mott Street factory of the Singer Company, about the year 1867, perhaps before.

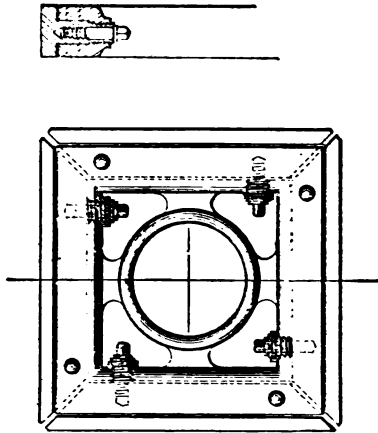


FIG. 205. — Device for Adjusting Square.

In 1868 rumors of a remarkable tool of this kind became the subject of shop talk among tool-makers in New York City, in Hartford, in Boston, and elsewhere, in consequence of the migrations and professional tours of members of that aristocratic guild of mechanics who had seen and described it.

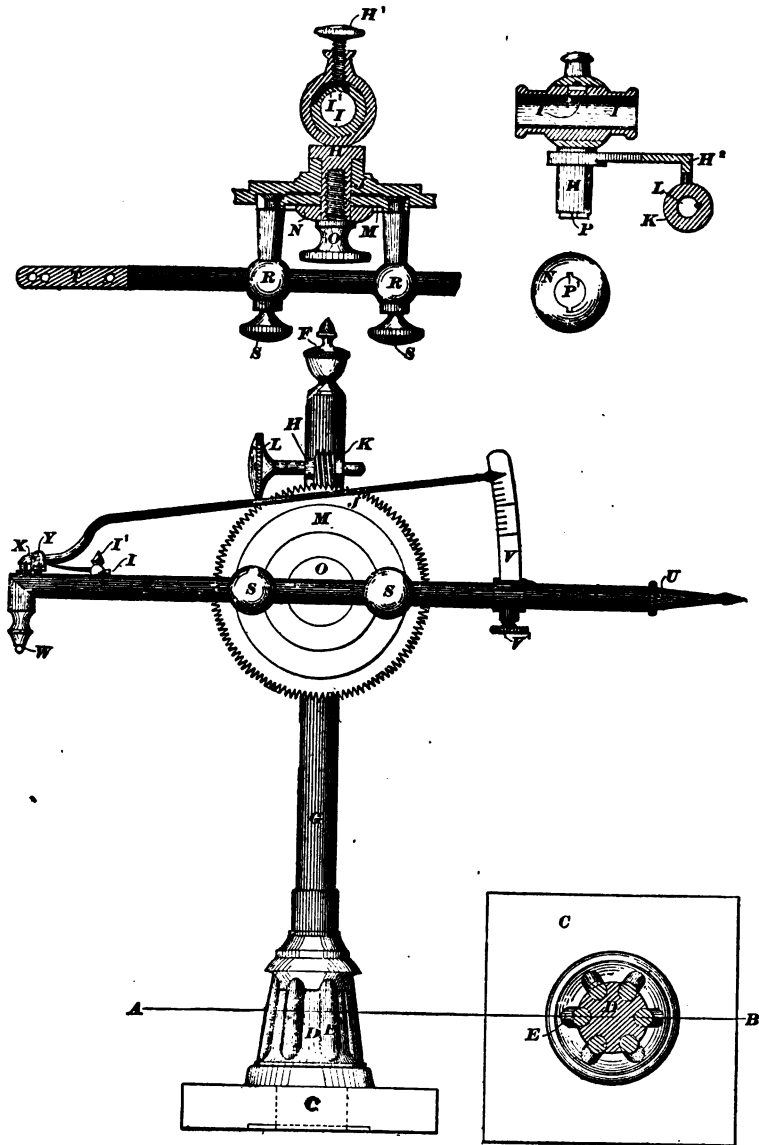
Tool-makers in those days were favored creatures, and Wincock was a king among them. He went into the shop in the morning dressed in faultless fashion, with gloves and silk hat. Imagine a man standing at the vise in lavender trousers and a duck vest, with his shirt sleeves rolled back, and a silk handkerchief for an "apron." The handkerchief corners would be tucked into his vest pockets for a fastening. Then believe the still

more marvelous fact that neither of the garments would be soiled, and the "apron" would last a week quite clean, and a man thus clothed would do as much first-class work as any other man then or since. Wincock was a whole man in the shop and out of it, and many of the old-timers remember his kindness of heart as well as his other peculiarities.

Later on the gage did good service in the United States Watch Factory, Marion, N. J., where Wincock arrived in 1874, and began a mercantile career. Having no further use for this tool, he gave it to a friend — first to show to some of his friends — and when he carried it back to him he said, "Keep it; you are the only man out here that I knew at the bench, and you have use for it, I haven't." He said that it cost him about one hundred and fifty dollars to make it. The friend still possesses it, and it has continually reflected credit on its designer. Every mechanic accepts its decisions when it is carefully applied to use. Its service to the owner personally is and has been incalculable. He has been able to prove perfections and detect errors with his instrument, which, without it, would in certain cases either have cost its value to provide as accurate special appliances for, or the results obtained would have been in doubt.

While the readings on the scale have no positive value, a person experienced in using this gage can detect differences of less than .0003 inch between one height and the other when they are compared. Fig. 206 is the front elevation of this gage. Fig. 207 is a horizontal section cut through the base, showing the construction of the peculiar ornamentation of that part, and the shape of the seat below it. Fig. 208 is a horizontal section through the head, and Fig. 209 is the view of the bracket *H*, showing its construction and the arrangement of the worm *K* upon it, as well as the hub *I* by which the whole head is attached to the support *G*.

We have never seen one of these gages made, and do not know how all the operations on it are performed, but we do know that they can be made. The base *C* seems to be bored, as indicated by the dotted lines, and the column *G*, with the sub-base *D* in one piece, is let through the base *C*, and fits it tightly. If this column, after it has been roughly turned, is carefully trued in a chuck on a dividing head, with the lower head outward, and placed before a drilling head at the proper angle and one hole



FIGS. 206 to 209. — Remarkable Surface Gage.

carefully drilled to the size of the small end of the taper plugs *E*, which make the convex fluting in the sub-base, then if the dividing head should be turned one-sixth the circle and another hole drilled, and thus for the remaining four holes each to the proper depth, all would be located in their proper position. It is understood of course that there is solid stock all about these holes when they are drilled, and that the holes extend by a short distance above the tops of the flute visible in Fig. 206. The plugs *E* seem to have the taper of the ordinary pentagon pin broach, so we presume they were reamed by hand. After reaming, they should be fitted with temporary plugs, which should be well greased and driven in snugly. The plugs should be of brass, so that the color may guide the operation, because it is probable that the joints will not otherwise be seen in turning and polishing the sub-base. After the column is completely finished in every other particular, these temporary plugs are removed and others of polished steel are driven into their places, giving the effect shown.

The cap *F* is an independent piece, and at its knurled flange is larger than the column *G*, to prevent the accidental removal of the head. The top of the column is drilled and tapped, and the cap *F* is provided with a screw stem which fits it, the joint being directly under the knurled flange.

The base *C* on this column is soft steel, and as such inferior because it catches grit and scratches on a surface plate; hence this base and column have not been used by the writer. In its place a hardened steel base of circular outline was made, to which was fitted a column double the height of this one. This overcame the trouble.

The bracket *H*, shown in Figs. 208 and 209, has within the hub *I*, which fits the column *G*, a spring gib or shoe *I*¹, which covers the point of the screw *H*¹, and prevents it from marring this column. The probable construction of the gib is indicated by these sections. We can find no joint, but believe the sleeve *I* to be inserted within the bracket *H* after the gib has been made, as shown. The worm extension *H*² seems to be a solid part of the bracket *H*, which it may very well be. It is presumed that the worm is keyed on, as shown in Fig. 209.

The worm gear *J* loosely fits the bracket *H*², and engages the worm *K*. It is recessed to receive the circular plate *M* of the

adjustable stock $M R R$. This plate is penetrated by the hub of the bracket H ; it is covered by the washer N , and clamped by the screw O . The dowels P enter the slot P^1 of the washer N , and prevents it turning. The worm K is used only in fine adjustment. When the screw O is loose, the adjustable stock $M R R$ may freely be turned in any position, because the plate M has a circular seat. When the screw O is partly tightened, the worm can adjust, but when wholly tight it holds the stock rigidly in its position.

The stock $M R R$ supports the gage arm T , and secures it to the required position by means of the screws $S S$. The beak of the arm T is bored vertically, of a parallel small size, to which is fitted very carefully the plunger W , so as not to shake but to be quite free, so as to slide end-wise with perfect ease. This plunger is kept in place by a shoulder which rests on the arm T , and it has a small hemispherical tip which receives the short arm of the index X . This index X is pivoted in the fulcrum post Y one-tenth of an inch from the center of the plunger W . It must have perfect freedom on its fulcrum, and be well guided in its position. The spring I is attached to the post I^1 , and has stiffness just sufficient to surely overbalance the weight of the index arm and keep a pressure upon the plunger W . The value of this gage as a delicate instrument depends on the adjustment of these parts, but when they are correctly set they will remain so for years. Since we have had this gage it has required two new plungers and one new spring.

The scale V has been lost many years. It is of but little value because it is found better to gage from a touch, or when the plunger W just touches the work so that the index at its outer end is perceptibly disturbed.

The scratch point U is hardened and screws into the arm T , precisely as cap F does into G . It has never been used.

The uses of these special features should be clear to every mechanic, where they apply to the detection or the confirming of rights and parallels, and it is only necessary to say that it is better practice to set the gage to the lower piece, or end, and at the higher place to place paper of uniform thickness under the base of the gage until the difference is equaled. Then measure the paper with micrometer gage. Handle the gage with a cloth tied to it whenever the hand comes in contact, because a warm



hand will expand a length of four inches about three thousandths of an inch at times. This has explained many contradictions in our experience.

In turning or grinding cylinders this gage will give the truth of the result, and frequently surprise the operator who imagines he is getting a perfectly concentric job. To do this, stand the gage on a flat, rigid surface, and set the front of the plunger *W* on the top of the revolving surface. The index will show whether it is true, eccentric, or not round. If true the index will stand dead still; if eccentric it will rise and fall regularly; if not round it will rise and fall irregularly.

Work in the lathe being trued up can be proved in the same manner by this gage. Lathe centers, milling arbors, and in fact all arbors, can be inspected by the same method. Face-plates and shoulders can be tried for truth as well as cylinders, by turning the gage arm one-quarter way over to meet them squarely. In fact, every rotation piece may be inspected perfectly for truth by this tool.

In the sketch here given, it is believed that the device is fairly well shown. Considering the fact that it was designed and made so many years ago, it is wonderful that it exhibits so much that has been proved to be correct practice, and if it were a production of to-day it would be considered as being ahead of progress rather than behind it.

A MICROMETER HIGHT-GAGE

The sketch, Fig. 210, is of a hight gage made on a plan of a surface gage. It consists of a central standard fixed in a base. The standard is threaded throughout its length 16 threads (or any number, for that matter), and then the threads are milled away, leaving a section on two opposite sides threaded, and on two opposite sides blank. The inside of the nut enclosing the standard is relieved on two sides to correspond. This enables the rapid moving up or down of the arm by simply loosening the clamp screw that binds it, turning it one fourth of the way around and then sliding it to the desired hight, swinging it round to a square position, and fastening the screw again. To locate the arm just right, a needle point is fixed on the top of the arm, that, with the marks on the standard, determines its location and sets

it central. The arm is extended and holds a round button of steel with hardened face. This button is bored and threaded to fit on a screw fastened in the end of the arm, as shown. Said screw is in a recess which is filled by the button. This button has 50 graduation marks on its circumference, and the screw

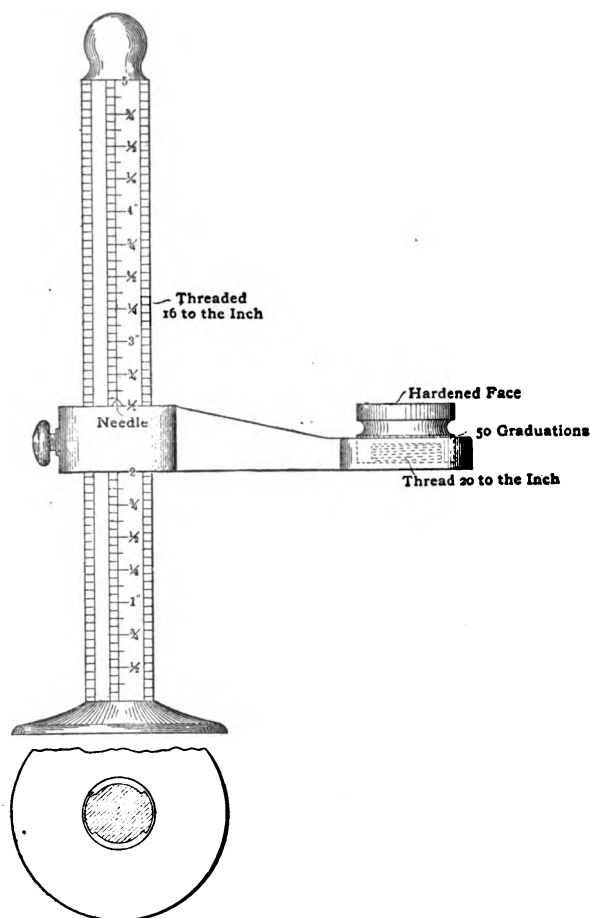


FIG. 210. — Micrometer Height Gage.

is threaded 20 to the inch, allowing adjustments of one thousandth of an inch.

The standard, graduated to sixteenths, makes a familiar reading, and the finer measurements can be obtained from the

micrometer button. The top face of the button when set at zero is equal to the height of nut on the standard at the reading point. The button is limited to two revolutions, as the arm can be shifted to make the difference, and a reading of less than zero on the button is possible, thus compensating for the difference, between the sixteenth threads on the standard and the twenty threads on the button.

The clamp screw is to have a soft metal seat to bear against the thread when fastening the arm in place; the whole to be finished, making a handy, quick and reliable tool.

SECTION VIII

OUTSIDE MICROMETER CALIPERS, TOGETHER WITH THEIR ATTACHMENTS FOR SPECIAL MEASURING AND GAGING.

MICROMETER FOR SCREW THREADS

THE first micrometer of the thread-measuring type with which we are all familiar was apparently made so nearly right that it has not seemed worth while to change it after mechanics have become so accustomed to its use. We suppose that if the screws had been cut originally 25 to 50 to the inch instead of to 40, the other divisions being made to correspond, the tool would have been just as satisfactory. And so when we propose improvements, it behooves us to make haste slowly in order that the improvement may become, like the micrometer itself, a permanent one.

The device we have in mind is for accurately measuring screws, and without reflecting on the efficiency of the other devices, we will say that this is a practical, satisfactory device, and so decided in a large screw-manufacturing concern after experimenting with everything known in this line. It is nothing but a pair of spherical points attached to a standard micrometer, as shown in Fig. 211. These points find a bearing just where the nut should fit the screw. If we have a nut and bolt perfectly fitting each other, and proceed to take a cut off the outside of the bolt, we cannot observe any difference in the fit; so that we very often find that the diameter of the nut inside cuts very little figure in the fit. What we propose is to have sets of spheres of standard sizes, with the standard projections from the face of the anvil. The spheres should be so large as not to strike the bottom on the standard screw, and small enough to go below the top of the "V." We estimate that one pair of spheres will answer for five or more pitches, and by having all fitted alike we take in fine threads of large diameter, and all odd sizes within

the limits of our tools. Then if there was not too much of an opening in the anvils, the micrometers could be used for ordinary work as well. The size when the spheres are in place should be stamped on each.

The usual custom in screw factories is to have a set of hardened and ground gages, and when making taps to take the size from the gages with the spherical point micrometers. Now if it was known what these sizes were, it would not be necessary to have the gages. These gages are so expensive as to debar all except the largest companies from enjoying the luxury. A maker of micrometers could get up an index giving all these

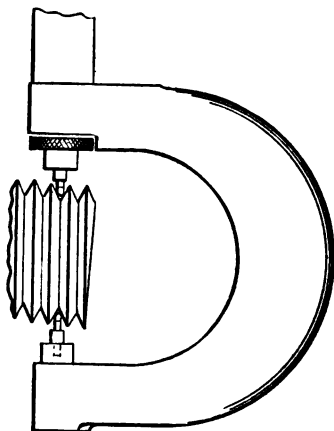


FIG. 211. — Micrometer for Screw Threads.

sizes for standard screws, and all screws could be ordered by these micrometers, thus:

Nominal size,	"V" thr. per inch.
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$\frac{1}{2}$ inch	13
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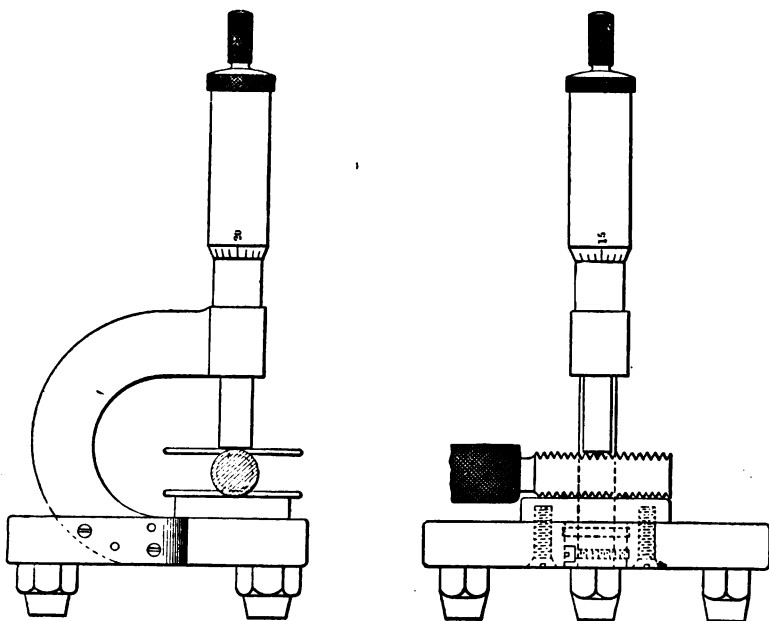
Bearing size measured with No. 5 point, .627.

It would not be necessary to mention No. 5 points, as each would have an index stating what pitches each pair of points was adapted to; and, they being alike, the man in San Francisco would measure exactly like the man in Boston.

MEASURING EXTERNAL SCREW THREADS WITH THE MICROMETER

Figs. 212 and 213 illustrate an improved method of measuring screw-thread diameters in the thread angle by using ordinary

micrometer calipers and wires of a suitable diameter. Without doubt this is one of the most accurate, as it has come to be one of the most universal, methods in use. Since we became acquainted with it and learned its usefulness, we have used it successfully on all available work, but find it very inconvenient to hold the wires, a screw plug and the micrometer calipers all at once. Therefore we have made a slight improvement in the tool, placing it upon a stand with three legs. A hardened and



FIGS. 212 and 213. — Screw Measuring Micrometers.

lapped disk is screwed on the top of the stand, as shown, as it gives a better measuring surface and is easier to handle.

In shops where the work is of great accuracy and only the practical minimum limit of error or variation is allowable, two sets of test micrometers should be provided, one for general use and the other for occasional reference only. The new micrometers should be given to the most skilled workmen for use on the finest work only, while those micrometers which have become worn, or are to a certain extent inaccurate, should be used on work in which a greater limit of error is allowed.

AN EQUATING MICROMETER

A very ingenious micrometer and recording gage of English design is illustrated in Fig. 214. The micrometer portion of this instrument follows the usual lines of construction, except that the barrel, which is usually knurled, is in this case formed into a multiple-threaded worm which operates a disk mounted below and carrying a series of figures representing various equivalents of the measurement made by the jaws of the micrometer. A bracket is fastened to the bow of the micrometer for carrying this worm disk, and there is also a fixed disk which stands in front of the revolving one and has a series of holes through which

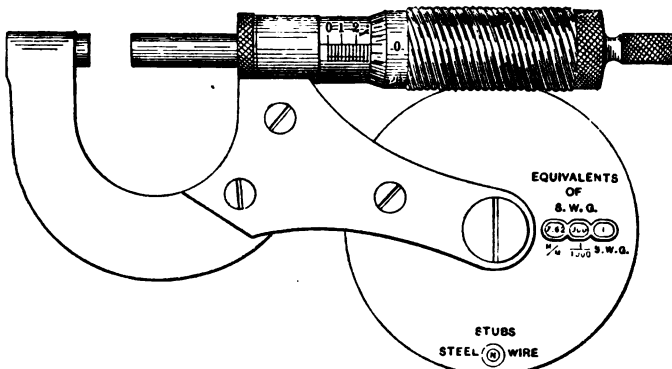


FIG. 214. — Equating Micrometer.

the numbers on the revolving disk become visible as the work is rotated.

As shown in the cut, the jaws of the micrometer are set at .3 inch, and on the dial may be read its metric equivalent 7.62 millimeter; also 300, denoting the number of thousandths; and 1, over S. W. G. indicating that .3 is the equivalent of No. 1 Stubbs wire gage. At the bottom of the disk is another dial for Stubbs steel wire, in which the size *N* is indicated. This, however, is slightly misleading as the letter will not occupy the exact center of the opening until the jaws of the micrometer have been moved .002 inch more, giving an opening of .302. A line on the worm disk corresponding with a similar line on the beveled edge of the hole in the outer disk indicates when the exact opening is reached. It is, of course, perfectly practical to apply this

arrangement to any kind of measurements for which the micrometer may be used, and in place of the equivalents here indicated we may have fractions of an inch, sheet metal gages, screw sizes, or any other equivalents that may be desired by the user. This instrument is manufactured by Grinshaw & Baxter, London, England.

6-INCH BEAM MICROMETER

The sketch, Fig. 215, shows a 6-inch beam micrometer that any mechanic can make with little trouble. After the forgings are shaped out, holes are drilled and reamed approximately .1 inch apart, and taper eccentric pieces to fit held in position by

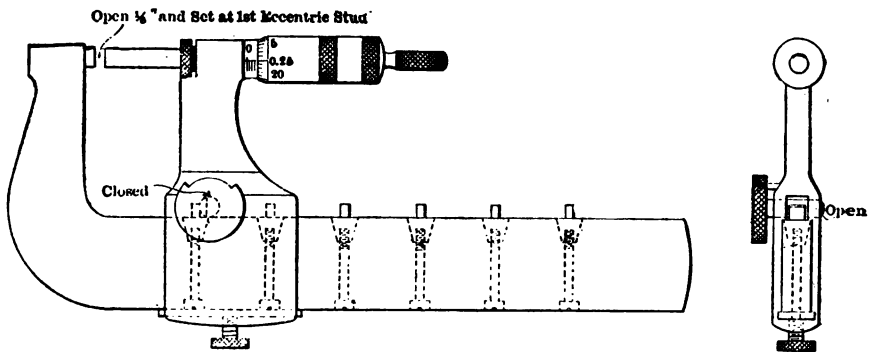


FIG. 215. — Beam Micrometer.

screws as shown. The pins can be easily adjusted 1 inch apart by turning the eccentric studs.

10 X 12 INCH MICROMETER CALIPER

Fig. 216 is a sketch of a pair of 10 x 12 inch micrometers that are very easily made. With the standard gages 3, 5, 7, 9 and 11 inches, one can set at any place. This one was made from one end to the other complete, as at the time the tool was made it was not possible to get micrometer heads. The beam is of tool steel — not annealed — and all screws are hardened.

HOW TO MAKE A LARGE MICROMETER

We have often thought how handy it would be to have a large micrometer. We could measure our work and tell just

how much was to come off, and as most feed screws are graduated it would be an easy matter to feed in so many thousandths, and the work would caliper just what we wanted it to. We happened to see a micrometer head at \$3.50. It struck us imme-

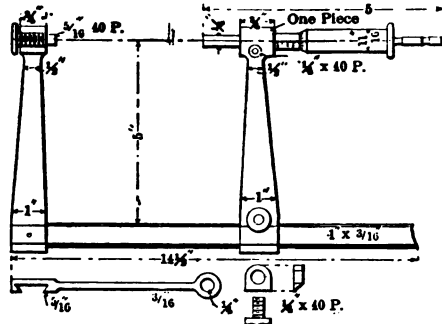


FIG. 216. — Twelve-Inch Micrometer.

diately that it was just the thing we could use. After seeing this micrometer head, we began to think there was no reason why we should not frame and attach that head to it, then all it would cost us would be the price of the head. We started in

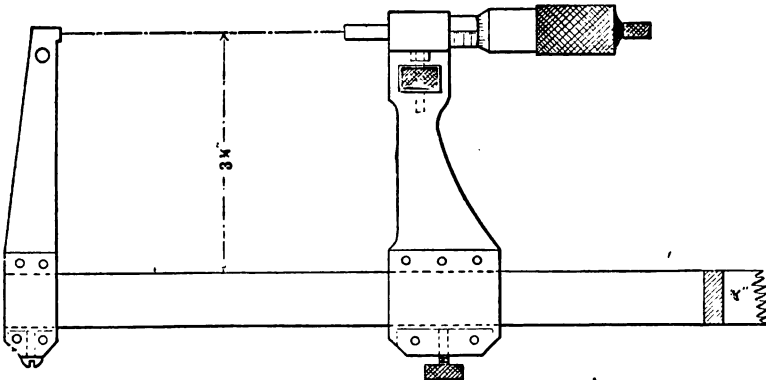
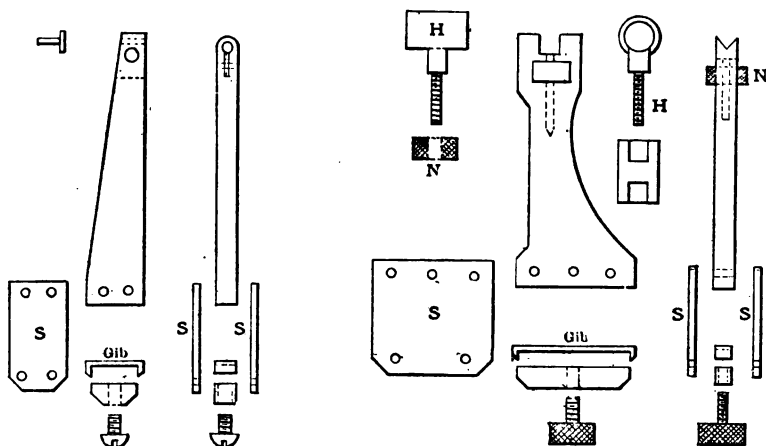


FIG. 217. — Large Micrometer.

and in due time finished the micrometer, which we have since found very valuable.

We think the drawings, Figs. 217 to 220, will clearly show the shape and relative sizes of the different parts required. The beam and two carrier arms, Figs. 218 and 219, were made from drawn stock; the side piece *S* was cut from sheet steel about $\frac{1}{16}$

inch thick. Holes were drilled and the parts riveted together with the beam between to keep them the proper distance apart. The riveting ought to be invisible after it is polished. The clamping device which holds the micrometer consists of a holder *H*, which by means of the nut *N* draws the micrometer down on the



FIGS. 218 and 219. — Details of Large Micrometer.

“V” cut on top of Fig. 219. The holder was made from a piece $\frac{1}{2} \times \frac{3}{4} \times \frac{3}{4}$, drilled and cut in shape, as shown by the dotted lines in Fig. 220. The screw was afterwards inserted and pinned. The advantage of having the micrometer detachable is plain, as it can be used elsewhere for distance as a depth gage. For accurate measurements distance rods are necessary. They can



FIG. 220. — Details of Large Micrometer.

be made in the following manner: First, run the micrometer out, reading 1000 against the anvil; then run it back to zero to fit in the 1-inch rod. Next move the micrometer back and run it out, reading 1000 against the 1-inch rod, and repeat the first operation, and so by continuing as many distance pieces may be made as would be desired. We recommend copying shop standards, if any such are obtainable.

As both carrier arms are movable, they may be put on any length of beam; but the size for measuring 6 inches, we think, will be found most convenient.

LARGE MICROMETER CALIPERS AT THE BRITISH WESTINGHOUSE WORKS

We are pleased to place before our readers a partial description of another set of large aluminum zinc calipers, of which one size is shown in Fig. 221, that may in a sense be said to be the descendant of those illustrated in Section I, having been made and being in use in the Manchester Works of the British Westinghouse Electric & Manufacturing Company, Limited.

No special novelty of design is claimed. The sizes range from 12 to 48 inches, each size up to 36 covering 4, and above that size 6 inches, each. The part of the design that consumed the most time was the adjustable tail spindle (anvil), as the shortcomings of the 10-thread-per-inch and half-nut clamp method had been noted. The method employed is much more expensive, but still not wholly satisfactory, the principal trouble with it being to keep it in a state for its proper use, which is part of the trouble with any tool that is used by many.

The tail spindles are of tool steel ground to $\frac{3}{8}$ -inch diameter, each clamped in a reamed $\frac{3}{8}$ -inch hole in tail end of micrometer frame; by two $\frac{1}{4}$ screws provided with knurled nuts, as shown in Fig. 222. This provision is ample with proper use. The tail spindle shown in Fig. 223 is hollow and provided with a $\frac{1}{4}$ -inch rod through the center. The anvil is hardened, ground and lapped. It was made $\frac{1}{4}$ inch because that is the diameter of the commercial micrometer screws used at the head of the micrometer frame. The accompanying sketches will plainly show the construction of tail pieces and method of clamping. With this tail spindle ready adjustment to zero is secured.

While these micrometers were being planned and made, no method of taking measurements with the larger ones had been decided upon. The chain and spring-supported stirrup leave much to be desired. Before the first measurement was taken with a large one, the method shown in Fig. 221, with the anvil at the top, had been decided upon, and it instantly proved its adaptability to the most delicate measurements; .0005 inch

variation in size being readily detected, as it would be with a 1-inch or 2-inch micrometer.

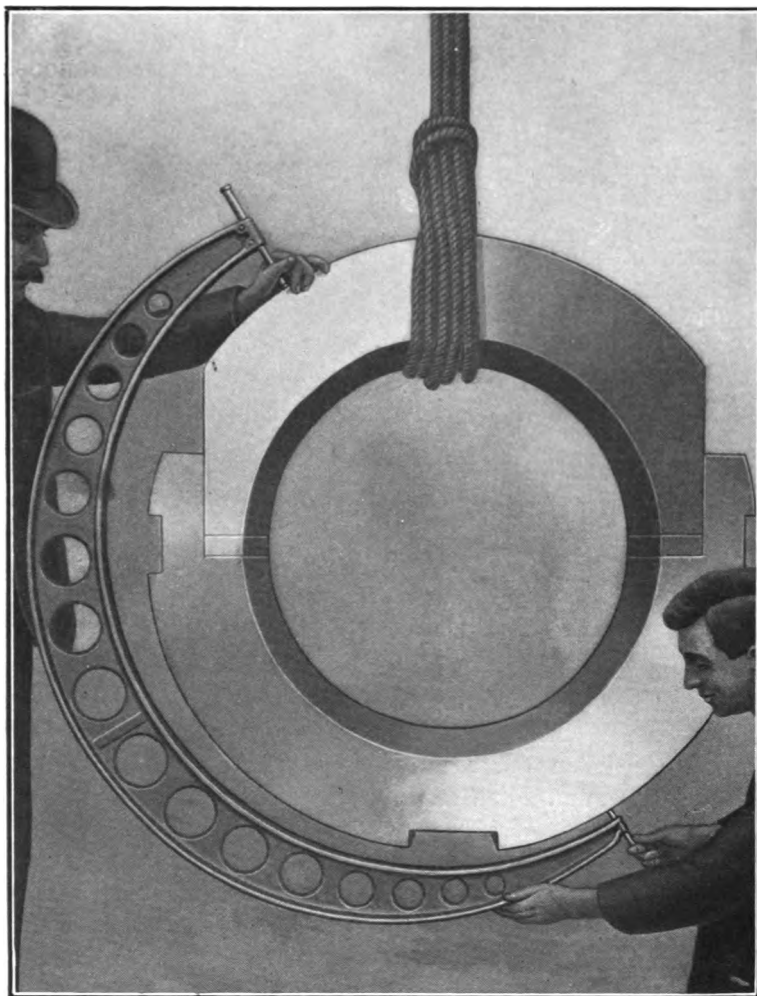


FIG. 221. — Large Micrometer.

The advantage of this method is obvious. The hand is at the point of contact; it is not also on the frame, distorting it with warmth; but the greatest advantage lies in the fact that the micrometer hangs in stable equilibrium. The workman says:

"It comes up to the work itself," not wanting to leave the highest point of the work. The only care necessary to secure this advantage is to place the anvil at the proper height, which height after the first few trials is generally guessed correctly to within an inch, the necessary adjustment taking but a few seconds.

By the half-tone the I-beam section and general outline of the frame will be seen. While there is a heavier section near the tail than the head, the fact that the instrument is to be used in all positions kept out any tendency to follow the well-known Thomas form.

Of course strict adherence to the principle of setting the micrometer while it is in the same position and supported in the

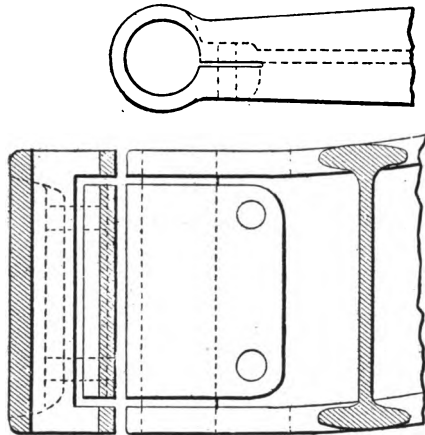


FIG. 222. — Knurled Nuts for Micrometer.

same way that it is to be while taking measurements is necessary. Checking back on the measuring rod after taking an important measure is to be insisted upon. Our own use of the suspended method, shown in the photograph, has been satisfactory, so much so that we feel it cannot be recommended too highly. It not only gives better results than any other method known to us, but it requires no "tackle" except a helper's finger or thumb placed against the work at the right spot. While this method does not secure the possibility of one man taking a measure by himself when using the larger sizes, the helper's part is an inert part; any other support that could be readily attached to the work, and movable, would do as well as the helper's finger or thumb.

A SHOP SET OF MICROMETER CALIPERS

The half-tone, Fig. 224, shows a set of twelve Slocomb micrometer calipers covering the range of sizes which it is usually desir-

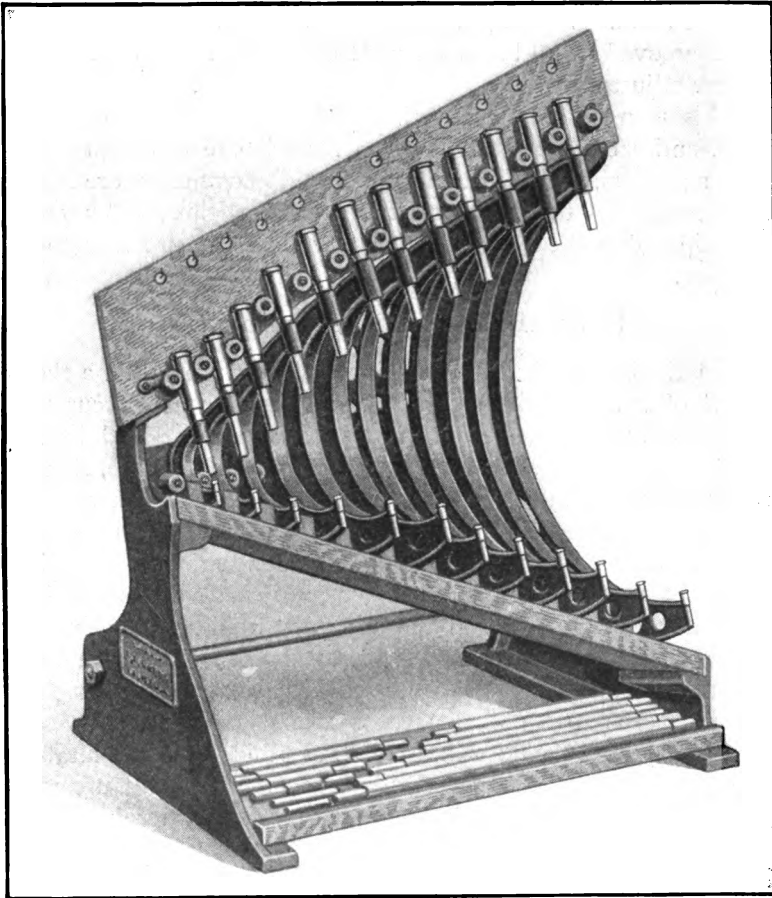


FIG. 224. — Set of Shop Micrometers.

able to determine with accuracy in the modern machine shop. The range of each caliper is 1 inch. The frames up to 6 inches are drop forged from bar steel, and the larger sizes are steel casting with openings in the web-like lattice work girders. All are finished in black enamel, and those above 3 inches are plainly

marked with figures indicating their range. Where the calipers are made for metric measurements the figures run consecutively all through the series, the first starting at 0 and going to 25 millimeters, the second 25 to 50, and so on, the last being 275 to 300 millimeters. The set as shown is of course intended for the tool-room. There are hooks above for the workmen's checks, and a grooved board below for a set of end measures for correcting the adjustment.

This plan of having a series of calipers, each complete in itself, and each with a range of an inch, is one to commend to shop managers, both because a number of micrometers are sometimes needed by the different men at the same time, and because no caliper should be very much larger than the size it is to be used for.

PRACTICAL SHOP USE OF MICROMETERS

A lathe hand of indifferent ability will work to within a thousandth of an inch of size if provided with a rigid caliper accurately set. The average machinist, with the same gage and in the same time, can work to within a ten-thousandth of a size, though requiring more time. These men could have nowhere near approached these limits with any degree of certainty using the ordinary caliper. Now the question naturally arises in the mind of the foreman alive to the economic possibilities of his position, whether or not a caliper of the necessary rigidity and accuracy could be furnished for general use in a shop at a reasonable cost? Limit gages are of course out of the question, for it would be beyond reason to expect a gage or several gages for every size used in a shop. The micrometers, however, fill the bill admirably, except for the expense of providing them for general use in a large shop, and the fact that the treatment they received — in a majority of cases — would not be such that they could be called instruments of precision very long.

The accompanying sketch, Fig. 225, is of an adjustable snap gage that has been used several years as part of a shop system of measurements, and has been found very satisfactory. These gages can be made at very small cost, especially if a number of them be made at the same time. The one shown here will take in anything up to $3\frac{1}{2}$ inches, the size of a gage most used in general lathe work. The frame is of cast steel, very light and rigid;

the rod and screw are $\frac{5}{16}$ inch in diameter, the latter having 20 threads per inch and locked when adjusted by the thumb-screw shown. We experienced no difficulty in making the rod and screw come exactly in line. It was done in the following manner: The holes were drilled in the lathe centers and then split with a hack-saw, whose soft back had been cut down until it would pass through the holes. The holes for the thumb-screws were drilled next, the top half to the whole diameter of the screw, and the bottom half tapped. A cast-iron sleeve, $1\frac{1}{2}$ inches long and $\frac{7}{8}$ inch diameter, was then made to fit snugly over the shank of the tap, which had been shortened by cutting off the square end. The shank was entered one half the length of the sleeve and tap and fitted with a pin. The hole for the adjustment

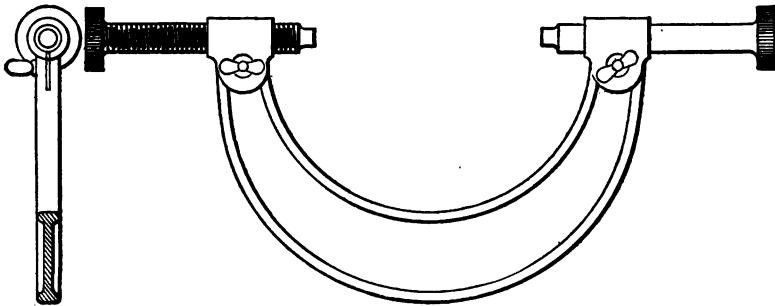


FIG. 225. — Adjustable Snap Gage.

screw was then tapped from the inside of the gage outward, the shank end of the tap being supported in line by a rod passed through the other hole into the sleeve and rigidly clamped by the thumb-screw. The tap was turned by a small bar fitting into holes drilled around the sleeve. The ends of the rod and screw are hardened and ground.

Under the system that has been employed and found so satisfactory we used 0.1 inch square steel wire for "points," as the men called them. If a man had certain sizes to turn that had to be quite accurate, he would cut off pieces of this wire about the length required, stamp the size on it and round and taper the ends so that they were about $\frac{3}{32}$ inch in diameter. These points he made approximately to size, and then gave them to the foreman, who tested them with a vernier caliper in his office, fitting each with a rub or two of the file, or perhaps a blow

of the hammer on a small anvil beside the instrument, to bring it up to size. It is then a simple matter when the work is roughed down nearly to size to quickly and accurately set the snap gage to, the point, making practically a solid gage. These "points" are very quickly made, and can of course be kept for future use. A man seldom requires more than the suggestion that he could get his points ready while his machine was running before he made a practice of doing so. For sizes over 10 inches we used a piece of broom handle or other wood, with a pointed wood in either end, flattened for wrench.

When extreme accuracy was necessary in the smaller sizes, a small piece of wood was drilled out and pressed over the wire to keep the heat of the fingers from expanding the gages while setting. These "points" cannot be beaten for inside gages,

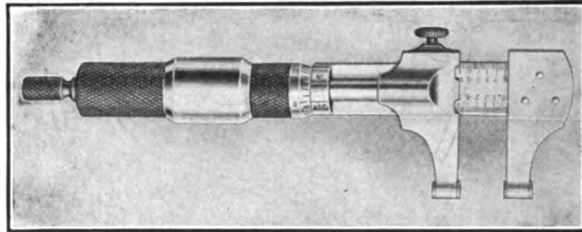


FIG. 226. — Outside and Inside Micrometer.

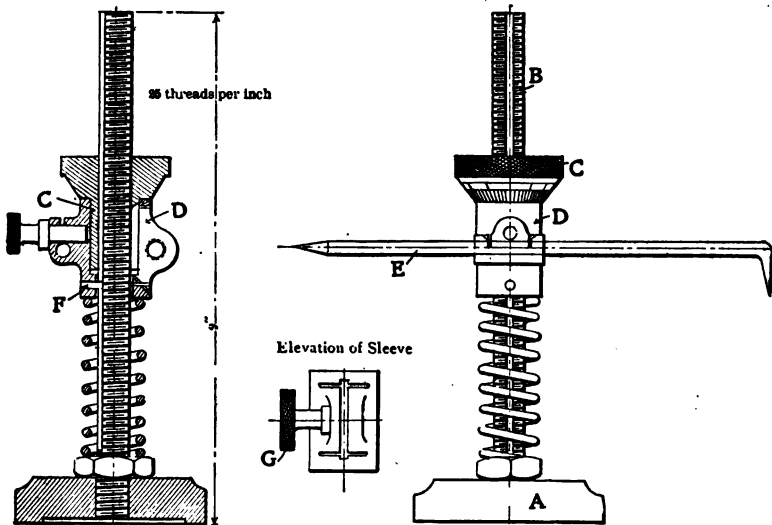
especially in getting the size of a hole already bored, when it is necessary to turn a piece to fit it exactly.

Besides this snap gage, we have a number of the regulation micrometer calipers of all sizes in the tool-room, and accessible to any one competent to use them; but it has been noticed that it was not long before there was hardly any call for them even by our best workmen, after they had become accustomed to the new system. We have never known a machinist who had tried the system but who was in love with it, and besides producing the work within the desired limits we found the total time consumed much shortened.

AN OUTSIDE AND INSIDE MICROMETER

The half-tone 226 shows a micrometer designed and patented by Frank G. Marbach, Medina, Ohio, for both outside and inside measurements, its range being from 0 to 1 inch,

and for the latter from $\frac{1}{8}$ to $1\frac{1}{8}$ inches. The thimble of this instrument has the usual graduations upon its periphery, but the graduations for the inch movement are placed upon the beam instead of on the hub of the head, rotating with the thimble while the usual spindle is replaced by a threaded shank affixed to the movable jaw. To compensate for the least motion between the nut (which is adjustable) and the spindle, two zero lines about $\frac{1}{4}$ inch apart are placed upon the hub, and the reading for the outside and inside measurements are taken from different lines, one being stamped "Out," and the other "In." The upper



FIGS. 227, 228, and 229. — Micrometer Scribing Block.

part of the beam is graduated from zero to zero, and the lower row of graduations giving inside readings starts at 625. While the tool shown corners but an inch travel, it is obvious that by increasing the length of the beam and making the jaw — which is now fixed — adjustable by inches, the caliper could be made to cover a range of, say, 6 inches or more.

MICROMETER SCRIBING BLOCK

Sketches in Figs. 227, 228, 229 show a very useful tool, a micrometer scribing block. It has an easy and fine adjustment for accurate lining out, but its chief advantage over the ordinary

scribing block lies in its use as a height gage, as differences are read direct, dispensing with paper or sheet gages, or in fact any gage. Its main parts are base *A*, screw *B*, nut *C*, sleeve *D*, and scriber *E*. The nut has a long bearing on the screw, and has a slit sawed up about a half inch in length. Screw *B* has a key-way in it in which fits pin *F*, which stops the sleeve from rotating. Sleeve *D* also is slit. Nut *C* is graduated with forty divisions, and rests against a line on the sleeve. The spring keeps spring *D* up against the nut. To lock the sleeve to the screw, knurled screw *G* is turned, which tightens the sleeve on the nut, which in turn is tightened on the screw.

MICROMETER SCALES

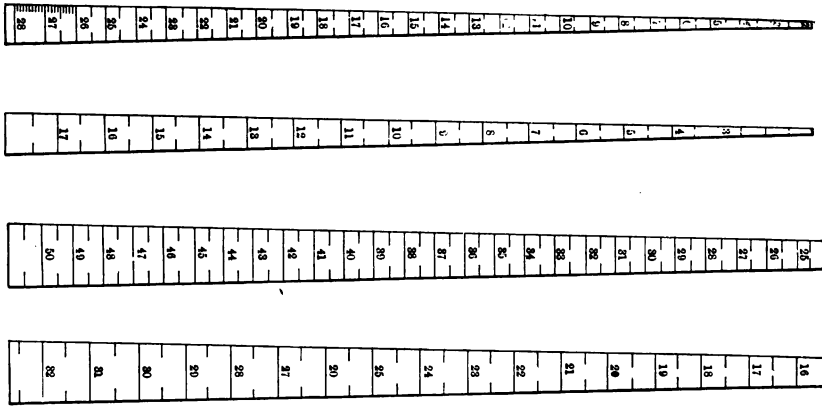
Having seen a set of scales like those shown in Figs. 230 to 234, in use for a long time by a workman in the shop, we concluded they would be of interest to others, and describe them as follows: The positiveness and accuracy found in their use certainly justify the employment of the term micrometer in naming them.

They are tapering steel scales graduated on both sides, one side having divisions of hundreds, and the other of sixty-fourths. Measurements can be taken very quickly, for the instant contact is made between the two points the reading is obtained; there is no yielding, as with a common, a vernier, or even a micrometer caliper. The different scales in the set make a series of overlapping measuring bars about $\frac{1}{8}$ inch thick, one scale supplementing the other after the manner of a set of taper broaches or reamers; and a surplus at the ends in excess of the graduated part of the scale is left for convenient handling.

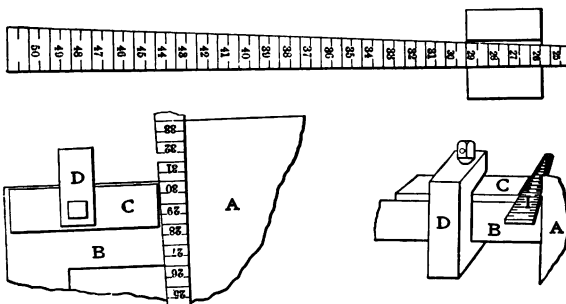
Take, for example, the scale shown in Fig. 230, and we have two divisions on the left hand, from 26 to 28, representing the distance required to increase the width of the scale from 26 to 28, and then subdivisions (common to the whole scale in the practice, but omitted in the drawings) give an easy advance in thousandths, making the latter more easily visible than sixty-fourths on the usual scale. Entering the scale, as shown in Fig. 234, a much more certain measurement of .29 is obtained than would be possible with the ordinary scale held with lines opposite the edges of the opening. The lines on the scale are made at

right angles to the lower sides, as shown in the cuts. It will be seen that the taper is $\frac{1}{2}$ inch to the foot.

In Figs. 235 and 236, let *A* be a part of the saddle on a planer or shaper, *B* the cross-head, and *C* a bar clamped by *D* to the latter. The bar *C* is clamped to the top of the cross-head in Fig. 236, instead of on the front, as in Fig. 235, and the scale is



Micrometer Scales



FIGS. 230 to 236. — Micrometer Scales.

used horizontally. If a dividing tool $\frac{1}{16}$ inch thick has made a cut into a piece of metal, and it is intended to make the groove in the work $\frac{1}{16}$ inch wide, then instead of measuring on the work or the tool, a piece *C* is brought up and clamped to the cross-head, and the $\frac{1}{16}$ -inch measurement taken with the scale as shown in Figs. 235 and 236.

Fig. 237 illustrates an accurate and convenient way of setting a surface gage point to height. A piece of work shown in Fig.

238 laid out in this way and tested up by the points, and bored out on lathe face-plate, came perfect.

Fig. 239 shows a positive method of intersecting lines, one at *K* getting a distance from the edge of the work by means of

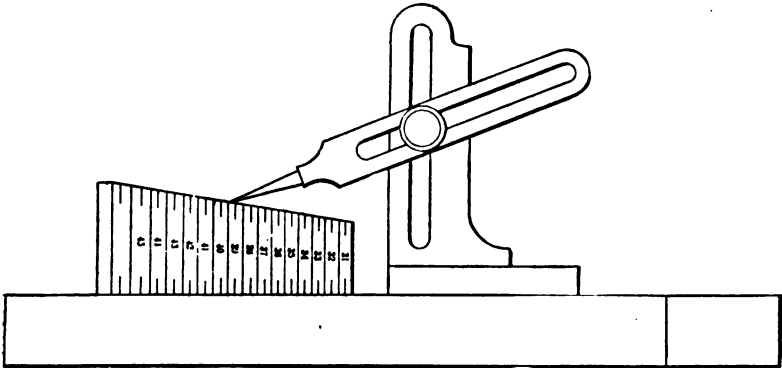


FIG. 237. — Setting a Surface Gage.

a block clamped as shown; and one at *L* giving a point on a line any required distance from the stud *M*.

A piece of metal is to be planed, say, from $1\frac{1}{4}$ to 1 inch thickness: Slide the scale between the tool and the planer bed to $1\frac{1}{4}$

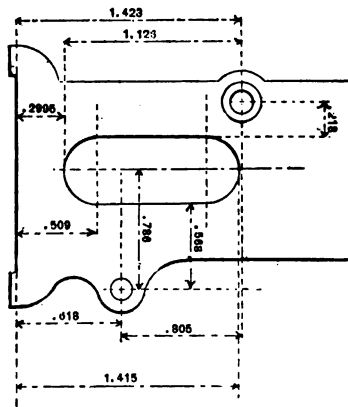


FIG. 238. — Work Laid Out.

and rough-cut one side, turn the work over, set the tool to 1.02 and do the same to that side. Then if .01 is right for a finishing cut, set the tool to 1.01 for one side and to 1 inch for the other; the work being fastened to the planer bed. Fig. 240 gives an

idea of the use of two scales together, giving here 2.756 inches. Decimal and common fractions are easily convertible by reversing the scale; and once determine the number of thousandths required

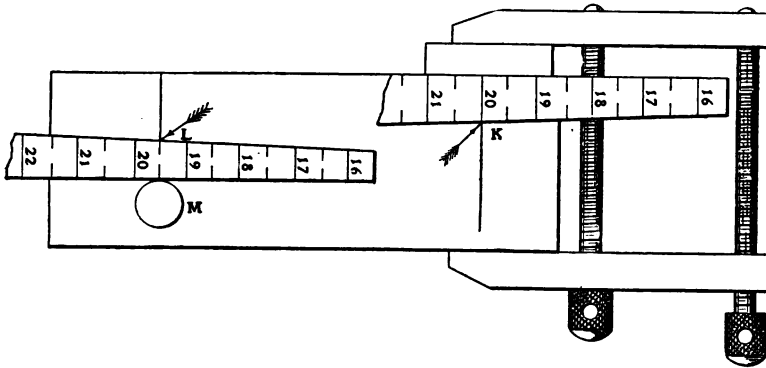


FIG. 239. — Method of Intersecting Lines.

for an easy, tight, driving or scraping fit, a cut can be taken with extreme accuracy for either by the use of these scales.

A MICROMETER GEAR TOOTH GAGE

Fig. 241 clearly shows all that is essential of a recently devised gage, and also the application of it. This gage is pat-

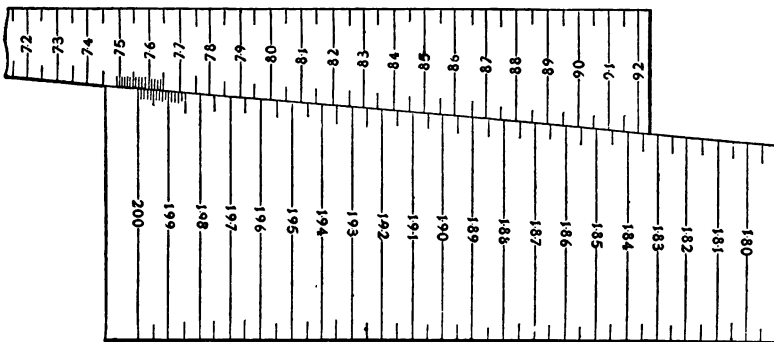


FIG. 240. — Two Micrometer Scales Together.

ented by J. Boulet, Beverly, Mass. As will be seen, its sole function is the measuring of the thickness of spur gear teeth at the pitch line, for the purpose of ascertaining their accuracy, and discovering any errors in the cutting. The jaw at the right

is fixed to the bar of the instrument, while the other jaw is moved in either direction by the micrometer screw, the nut of which is fixed to the other end of the bar. By this means the thickness of the tooth may evidently be measured as accurately as in any other application of the micrometer, provided the points of the measuring jaws are brought to the proper location on each side of the tooth. The positions of the jaws relatively to the tooth are determined by the central vertical micrometer screw. The point of this screw is always central relative to the jaws, and

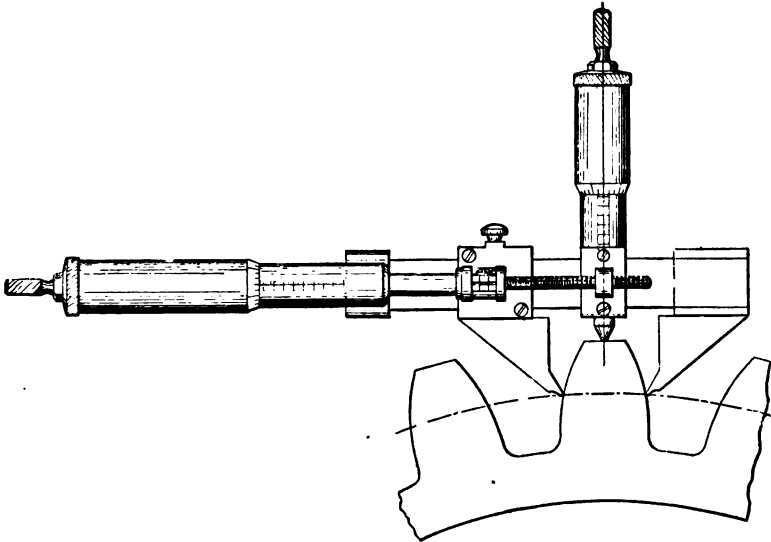


FIG. 241. — Micrometer Gear Tooth Gage.

the micrometer adjustment brings the jaws to the correct height for the pitch line, according to the pitch of the gear tooth to be measured. To keep the vertical screw always central between the jaws, it must evidently move in the same direction as the movable jaw, but at half the speed. The small horizontal screw which moves the block which carries the central or depth micrometer is a continuation of the screw which moves the thickness measuring jaw, but the pitch of the screw is only one half that of the larger screw, and the pitch is also reversed. Thus, if the principal screw is forty to the inch and right-handed, the small screw for moving the depth gage must be eighty to the inch and left-handed. This instrument will, of course, do its

work as accurately as any other micrometer, employing this familiar means of minutely indicating the movements of the measuring jaws, provided it is accurately made, which, of course, it must be.

MICROMETER ATTACHMENT FOR THE LATHE

The sketch, Fig. 242, shows a device for clamping a micrometer head to the lathe bed. The inner side of the 45-degree angle is left short so that the fixture is not unnecessarily high, and also to allow it to be removed from the ways of the lathes with the fewest possible turns of the knurled head screw. The micrometer head is held in place by means of a brass screw, so

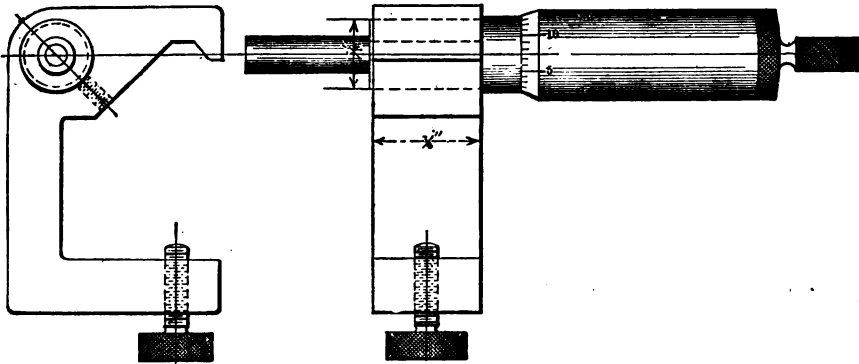


FIG. 242. — Micrometer Attachment for Lathe.

that it may be readily removed if wanted for any other purpose. When turning where the distance from one shoulder to another must be very accurate, or where a given amount is to be faced from a piece of work, the fixture should be clamped so as to allow the carriage, the barrel being turned, to keep the micrometer spindle in contact with the side of the carriage until the required distance has been traveled.

MICROMETER CALIPER FOR MEASURING THE RADIUS OF SPINDLE DRILLS AND SIMILAR PIECES IMPOSSIBLE TO MEASURE DIRECTLY

The principle of this gage is shown in the sketch, Fig. 243. As we have a constant angle of $\frac{130}{2} = 65$ degrees, the line will

always be a fixed ratio with the correct radius of the piece to be measured. So we have only to multiply the radius of the piece to be measured by the constant 1.103 and set the gage to this amount. The constant is found by the reckoning:

$$1 = \frac{r}{\cos. 25^\circ} = \frac{1}{0.90631} = 1.103.$$

To set the caliper at zero, it is necessary to have a measuring disk, say 10-millimeter diameter, then we reckon the distance, Fig. 243, for this disk as follows: $5 \times 1.103 = 5.515$, and add to this $r = 5$, giving 10.515; to this amount we set our screws, then put the disk between the point of the screw and the anvil, and tighten the anvil when the gage is ready for measuring any diameter up to 20-millimeter radius. For larger diameter, we

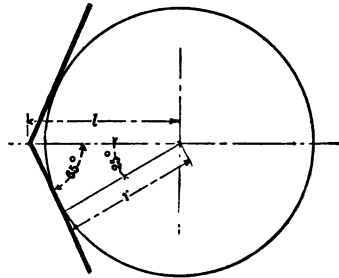


FIG. 243

make the same arrangements with a measuring disk 30-millimeter diameter, and are then able to measure the radius of the pieces up to 60-millimeter diameter.

This gage is especially valuable in milling to the center of things where the periphery is interrupted, as in spindle drills, etc., a section of which is shown, Fig. 244.

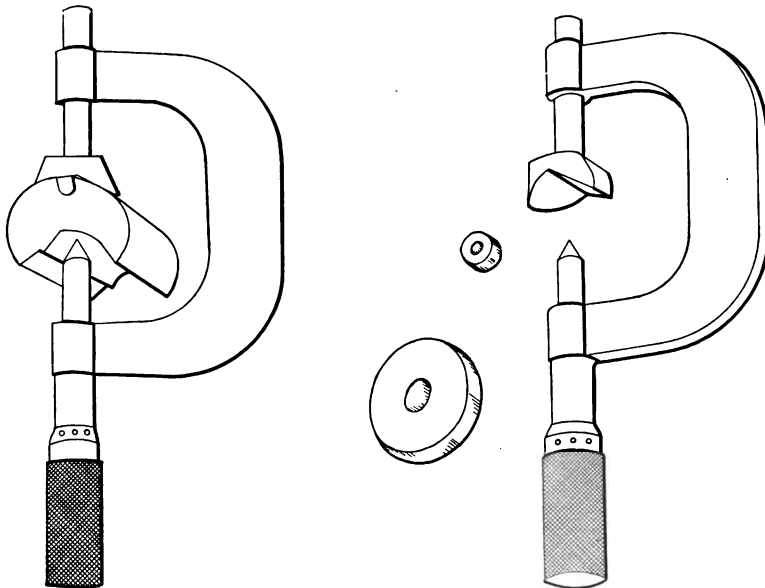
Example:—To stake a center of a piece 19.5 diameter, we set the gage according to the first case and reckon: 9.75×1.103 —amount we ought to read on the micrometer scale when the center has been reached. Fig. 245 shows the instrument with the measuring disks.

A MICROMETER STOP

Every mechanic knows when he is facing a piece of work, how difficult it is to move the lathe carriage just the right amount when there is a thousand or two for the finishing cut.

The stop, Fig. 246, is clamped to the lathe bed at any convenient point, and adjusted to abut against the carriage, when reading can be taken and the carriage moved accurately any distance within range of the stop, in this case 1 inch. It can be used for a variety of work, such as recessing an exact depth below a finished surface, stepping from one surface to another by means of a distance piece between stop and carriage, etc.

Having a piece of work on the face-plate, and after measuring the location of a hole just bored, it was found to be just one thou-



FIGS. 244 and 245. — Micrometer Radius Gage.

sandth out of center. It was but little work to clamp the stop to the face-plate, take a reading from the side of the work, loosen bolts and tap over the right amount by measurement.

TESTING MACHINE TOOLS WITH A MICROMETER CALIPER

It is of course obvious that the micrometer caliper can be applied in many ways, and for the purpose of making many other tests of the accuracy of machine tools besides those given elsewhere in this book. We present herewith a few of these, and

many others will readily suggest themselves as the occasion for them arises. It is often desirable to test a drill press, to see whether the spindle is at right angles with the table or platen.

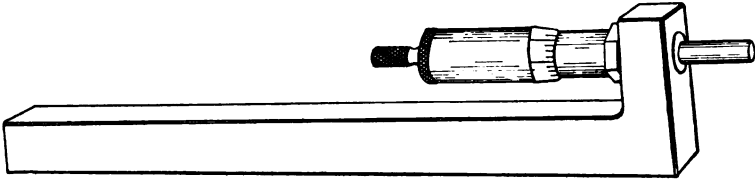


FIG. 246. — Micrometer Stop.

A test for these is shown in Fig. 247. A parallel strip or piece of bar stock *A* is clamped to the end of the spindle, or if more convenient to a piece held in a chuck. On the end of this piece,

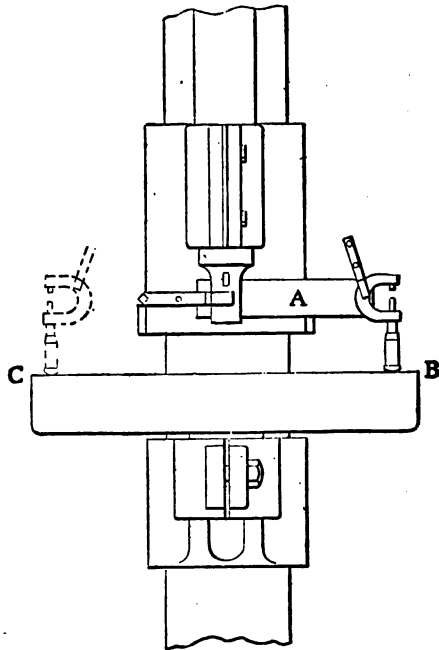


FIG. 247. — Testing Drill Press Table.

and near the end of the table, is clamped the caliper, as shown. A measurement is then taken at *B* and noted, and the spindle and caliper turned around to the position shown by the dotted lines, and another measurement at *C*, when the alignment side-

ways may be noted. Two other measurements, one in front, the other at the back, will complete this test.

Sometimes it is desired to know the deflection of the platen under the pressure of drilling, as of course that affects the alignment of the machine and the quality of the work turned out. For this purpose the caliper should be clamped by any other convenient means, which will readily suggest itself, to the sliding head of the drill spindle, and in such a way as not to interfere with the work. The caliper may be extended down to measure the table or platen direct or two blocks on the table, or to work itself, as may be most convenient.

Before any pressure is put on the drill spindle, a measurement should be taken and noted; then the drilling commenced, and after the drill has started properly, the spindle stopped with the feed still on and another measurement taken, when the deflection under working conditions may be noted.

When a drill press is used on one line of work, it is by this means an easy matter to throw the spindle out of line just enough to compensate for deflection and be right under working conditions.

In using the ordinary machine vise, such as we find on the planer, shaper, and milling machine, we often want to know whether or not the fixed jaw is square, or, in other words, whether work held against it by the movable jaw will be planed or milled square and true with that side. We usually find it out by putting the work in place and taking a cut over it and then trying it with a square. In Fig. 248 is shown what will usually be found a quicker and more satisfactory method.

The square *A* is clamped against the solid jaw *B* by a small bar of brass or other soft metal or stick of wood, as shown at *C*. The caliper is clamped on a tool shank held in the shaper or on the milling machine arbor, as the case may be, and a measurement taken to the edge of a square blade, as shown at *D*; then by moving the slide another measurement is taken, as shown by the dotted lines at *E*. This of course will show at once whether the jaw is at right angles with the machine slide, which is necessary to produce square work.

When the work is supported on parallel strips or directly on bottom *F* of the vise, to find whether that face is parallel with the slide of the machine, it is of course only necessary to dispense

with the square, and opening the vise to its full extent, apply the caliper direct to that surface at not less than four points, or at the extreme corners, which will show at once how the work is expected to come out.

It is often desired to set the vertical tool slide of a shaper or planer nearer vertical, or at right angles to the platen, than may be done by the graduations. If a machine vise with a square jaw be at hand, it may be done, as shown at Fig. 249, in which the parallel strip *A* is held against the jaw *B*, as in the square in Fig. 248; then by clamping the caliper to a tool shank

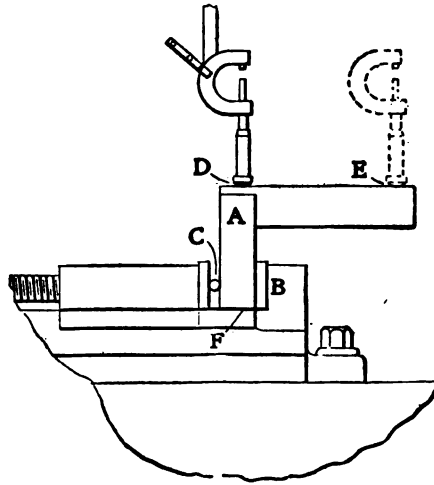


FIG. 248. — Testing Machine Vise.

held on the slide, measurements taken at both ends of the parallel strip by running the slide up and down will show whether the slide is in its proper position or not.

This also affords a ready means of setting the head exactly at any desired slight inclination, so as to produce slightly tapering work of definite proportions. Say, for instance, it is desired to plane down a surface nearly vertical, but with an inclination of, say, .005 inch in 4 inches. In such a case it would be necessary to make two marks upon the piece *A*, Fig. 249, four inches apart, then set the head so that the micrometer would show the required difference of .005 inch when applied at the two different points thus marked.

Another way of testing which would usually be much more handy for the planer, especially where the vise is not so much used, is to clamp to the platen a square with its blade standing vertical and crossways to the platen, and make the measurements to the edge of this blade, as shown on the parallel strip held in the vise in Fig. 249.

The truth of the two screws that operate the cross-rail of a planer, which is all that it is usually desired to know, may be very easily and quickly tested by clamping the caliper to the end of a long bar of steel, such as is used for tools and clamped in the tool-

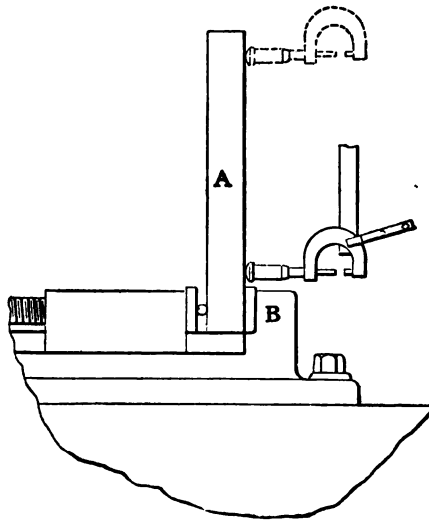


FIG. 249.—Testing Machine Vise.

block. Starting with the cross-rail down near the platen, make a measurement near one edge, then run the saddle and tool-block to the other side and measure again. By now raising the cross-rail, say 6 inches, and letting down the bar carrying the caliper, measure again on both edges of the platen. Continue this operation until the full height of the housing is reached, and if a record of the readings has been made, it is easy to see at a glance how near alike the screws are, and if there be an error just how it is, and how much.

Most milling machines, and especially universal ones, have graduated dials reading to thousandths of an inch on most all

the slides. On such machines the caliper, as shown, used in these various tests, is not of so much advantage, as the reading may be taken direct from the machine itself when testing the platen for truth in both ways with the cutter arbor and spindle. But on such machines as do not have these graduated dials, the clipper method of testing and for setting the work in the proper way upon them will be found both quick and handy, and after the habit of using it is acquired, quick and accurate setting of work will be greatly facilitated.

There are test indicators on the market which read to thousandths of an inch over quite a range, and some of them would answer the purpose of these tests much better than the micrometer caliper, as they would be much quicker and would in themselves take care that the contact pressure is the same at all readings. Special indicators have not found a place in this article for the reason that they are special tools, while the object of this is to show how the tests may be made cheaply and quickly without special tools.

TESTING THE ACCURACY OF A LATHE WITHOUT SPECIAL TOOLS

When the new lathe comes into the shop, and sometimes in the case of an older one, it is desirable to know about how true it is, or more accurately speaking, how its various parts line up one with the other. Sometimes it is not merely desirable to test the lathe, but may be necessary, and perhaps if it were not considered to be, and usually made, such an expensive job, more lathes would be tested and made right when found not to be true, and very likely a great deal of time would be saved by the ability to turn out better work.

There are many ways to test lathes by the use of specially devised indicators and micrometers, and good straight-edges and round true arbors; and a good many articles have been published describing these tools and methods which are well enough for manufacturers of lathes, but not at all adapted to the needs of the lathe users. What we want to consider now is how to do the job without special tools or fixtures, and with just the ordinary stuff that is found kicking around the floor of almost any jobbing shop, and can be easily had in any other kind of a shop. At this date there are not many machine shops

in this country which do not possess at least one ordinary 1-inch micrometer caliper, and this we will use in the testing of lathes. Shops which do not possess such a caliper do not usually want to test lathes. The caliper is not absolutely necessary, however, and the job can be done without it, but can be done more quickly by using the caliper, which will not only show when a thing is out, but also just how much, which is exactly what we want to know.

Perhaps it will be well to begin with the foot-stock and see if its spindle is parallel with the ways or shears of the bed, a necessary thing if good work is to be done.

For this test we will consider a lathe of about 16 inches swing and 6-foot bed. The first thing we will need is a piece of centered shaft, or an arbor, about 2 inches diameter, 4 feet long. It need not be either straight or round, but should be well centered and square up true on the ends. Put this arbor on the centers with

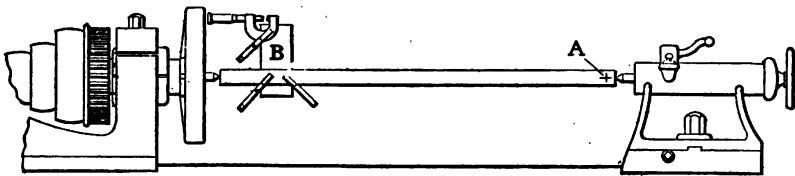


FIG. 250. — Testing Lathe.

the foot-stock spindle clear back. Make some kind of a mark, as with chalk, near the tail center end of the arbor, as at *A*, Fig. 250.

In the tool-post of the lathe mount the 1-inch micrometer caliper, as shown in Fig. 251, with the thimble end to the work. This may be done by bending a tool shank or piece of iron, as at *A*, Fig. 251, and the caliper can be held in place upon it by almost any kind of a clamp that comes handy, such as *B*. By moving the carriage and tool-block, bring the thimble end of the caliper near the mark *A* on the arbor in Fig. 250, open the caliper to bring the thimble in contact with the arbor — though it would be a good plan perhaps to interpose a piece of paper between the caliper and arbor, which may be pulled between them in order to always get about the same contact. When the proper contact is made note the reading and back off the caliper by turning the thimble, but do not move the tool-block. Now loosen the foot-block, and run the spindle out to near the end of the screw,

and clamp again; then measure again just as before, and if the two readings agree, the tail spindle is in line sidewise. The caliper should now be changed to the position shown in Fig. 252, and the two measurements taken on top of the arbor the same as taken at the side. The mark *A* is now turned upward, since we are assuming that the arbor is not true, and this enables us to measure from the same spot for each measurement of a given test.

Perhaps the thing to do next is to test the truth of the live center. Measure to the spot on the arbor near the live center, either from the side or top, then turn the spindle, say quarter way around, holding the arbor in the original position, and measure again; repeat this about four times, and if all the readings agree the center is about right.

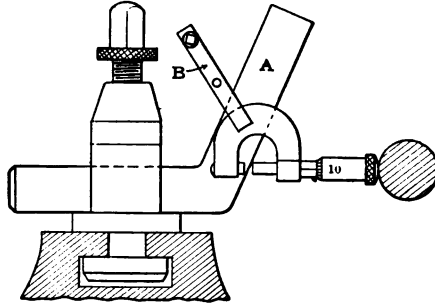


FIG. 251. — Micrometer Test.

A way to test the center hole is to put the center in place, being careful to have it clean, and turn or grind it true; then remove and put it back again turned half way around from the first position, when the error of the hole, if there be any, will be double and may be more rapidly measured. Sometimes the front and back end of this hole are not true with each other, and in this case about the only way to test or find out how much it is out is to fit a piece to the hole, having a straight end, which, in this case, should be both true with the taper shank and straight. By putting this in place and measuring with the caliper held as in Fig. 251 at both ends and turning the spindle, it may be seen at once whether the hole is in its proper place.

Next we will line up the head and tail centers. Put the caliper in position, Fig. 251, and measure to the marked spot on the

arbor, then turn the arbor end for end and run the carriage along without changing the cross-slide, and measure again. If the two readings agree, all right; if not, adjust the foot-stock until they do agree, when the center will be in line with the shears.

To find if the centers are the same height, place the caliper in position, Fig. 252, and measure near each center by reversing the arbor as before.

To find whether the live spindle is in line with the centers and shears, clamp a parallel strip or rough piece of bar iron, such as *B*, Fig. 250, on the arbor near its end, and on that clamp the caliper as shown. Then with the largest face-plate in the spindle, and a mark on the plate (as it is not assumed to run true

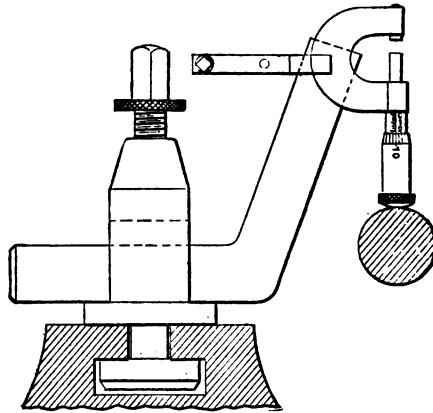


FIG. 252. — Micrometer Test.

at all), measure to the plate with the mark at the top and again at the bottom by turning both the spindle and the arbor. Any difference in the readings will show at once which way the spindle inclines vertically. Repeat this operation by measuring both at the front and at the back, by which the alignment laterally with the shears may be noted.

To find whether the cross-slide is at right angles with the spindle and shears: If a good straight-edge be at hand, one way is to take a cut over the large face-plate, and apply the straight-edge, when, if the spindle is in line with the shears and the plate is flat, the cross-slide will be shown to be at right angles. But perhaps it is not convenient to take a cut right over the plate, and so we will consider a way of doing it without any cutting at

all. Mount the caliper on a tool shank, as shown in plan in Fig. 253, with the thimble pointing to the face-plate. Most tool-blocks will not go far with the thimble pointing to the face-plate. Most tool-blocks will not go far back of the center, so the caliper should be mounted somewhat in front of the tool-post, as shown, so that it may travel an equal distance each side of the center, and should go as far as possible from it in each direction. Measure to a mark on the face-plate, as shown in full lines at *A*, then back of the thimble, and move the tool-block and caliper to the position shown by the dotted lines at *B*. Turn the spindle to bring the mark on the plate to that side and measure again,

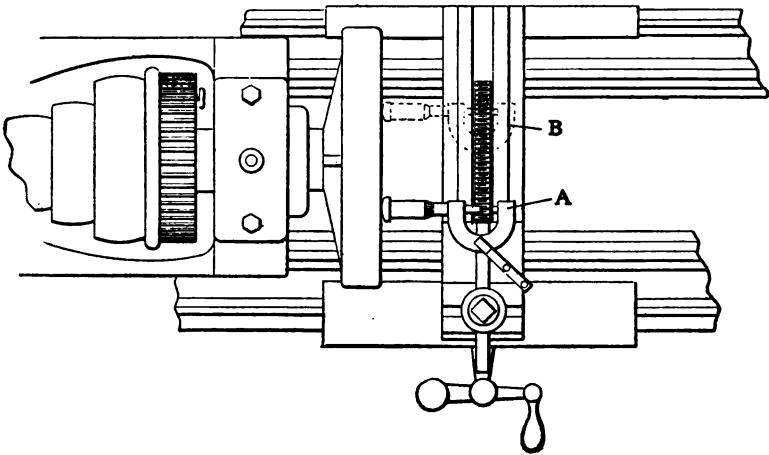


FIG. 253. — Micrometer Test.

and if the two readings agree the cross-slide is at right angles with the spindle and also with the shears, if the spindle is properly in line; if not, its position may easily be found by noting the alignment of the spindle, as shown by the preceding test.

It may be preferable to make this last-named test with the micrometer arranged as in Fig. 250, except that the piece *B* should then be nearer the middle of the length of the arbor. A piece of any convenient form can be held in the tool-post and brought into contact position with the micrometer, first in front and then at the back of the arbor, rotating the latter upon the center to bring the micrometer into position, and moving the cross-slide by the screw. This method has the advantage of

eliminating any error that might arise from end motion of the spindle when rotating it; but it is to be observed that it shows only whether the cross-slide is square with the lines of the centers, and nothing more than that. If, however, the centers have previously been lined up with the shears by the method described, then this last-named test also shows whether the cross-slide is square with the shears or not. And if the spindle has been previously lined up with the line of centers, as previously described, then this last-named test shows also whether or not the cross-slide is square with the spindle.

It will be seen that the micrometer caliper is not absolutely necessary for any of these tests, as by the use of a common cap screw, fitted rather snugly in the piece held in the tool-post and on the arbor, all the tests may be made, and perhaps just as accurately as with the caliper, but with the disadvantage of not indicating how much the various points are out of position.

The method of testing the lathe is not given with the belief that it is the very best that can be used, but it is a very cheap and simple method covering most of the points desirable to be tested, and at a cost that will not prohibit its frequent use.

The use of the end of the thimble of the micrometer caliper is not a new idea at all, though perhaps it is as applied in this way and for this purpose. One of the very early calipers, made in France, and illustrated in the *American Machinist* some years ago, had a hardened contact point on the end of the thimble, and another extended from the ordinary anvil; the caliper was intended for internal measurements as well as for the ordinary outside work.

A NEW SWEDISH COMBINATION GAGING SYSTEM

An interesting and rather unusual set of gages of Swedish origin has been brought out by the Grönkvist Drill Chuck Company of Jersey City under the name of the Johansson Gages. The remarkable features of this system are the exquisite finish of the surfaces which enables the use of them either singly or in multiple by the simple process of wringing them together. In Fig. 254 the complete set of gages is shown in its box, which is $10 \times 15\frac{3}{4}$ inches and weighs $7\frac{1}{2}$ pounds. In the various series in this case are gages ranging from 0.1001 to 0.1009 inches in thickness rising by 0.0001 up to gages of 2 to 4 inches rising by 1 inch.

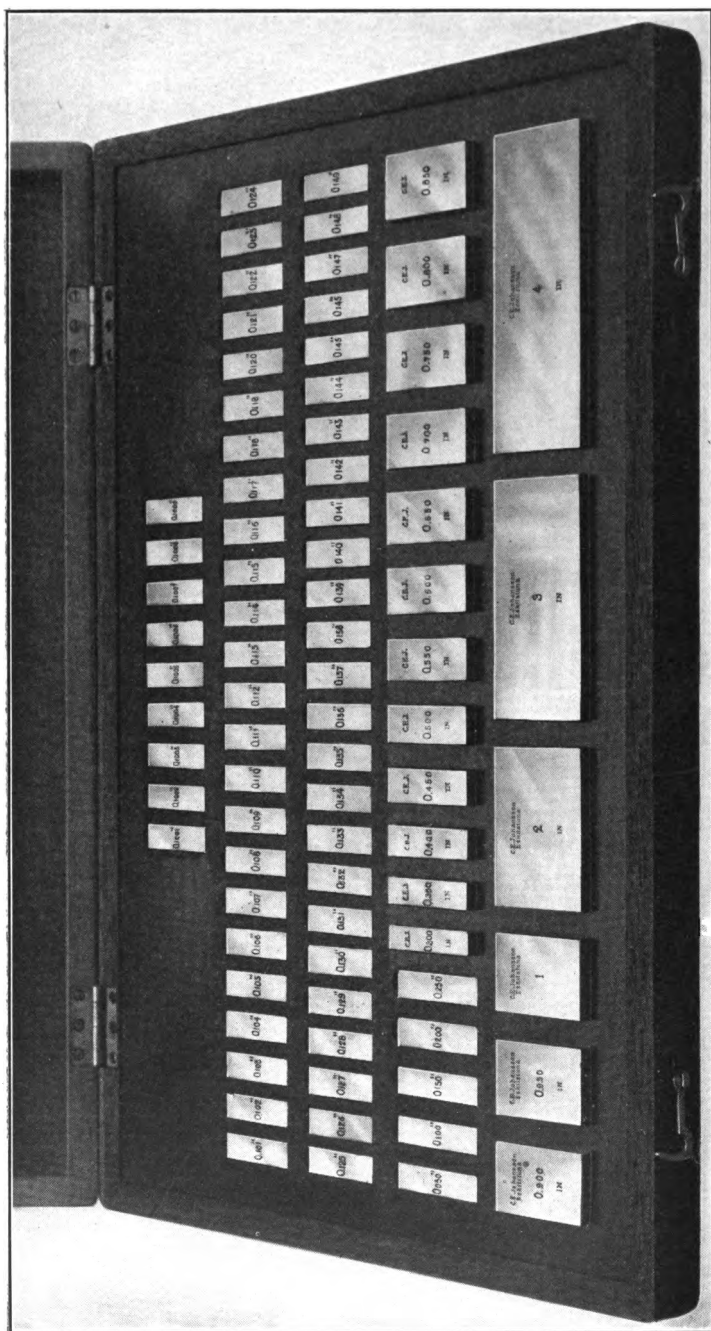


FIG. 254.—A Set of Swedish Gages that is Remarkable in Many Ways.

It will readily be seen that by taking proper selections of these gages and wringing them together a complete gage can be made of any size desired. It is estimated that at least 80,000 different sizes may be made and in all probability this is a low estimate. No thickness has yet been discovered which cannot be accomplished by the various combinations, and the majority of the points can be reached by several different combinations enabling an accurate checking up in case of doubt.

Fig. 255 shows 22 gages supporting each other horizontally. It gives the best idea of the manner in which they are to be used,

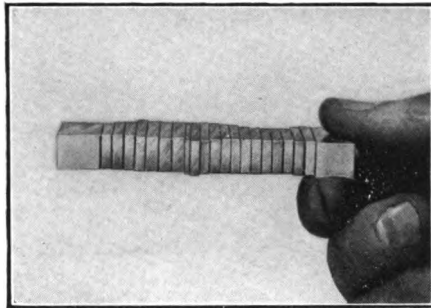


FIG. 255.—Twenty-two Gages Support Each Other.

and yet when built up in this manner the *feel* of the gage is the same as of a solid piece and this holds for any combination.

Fig. 256 shows one large piece and two small pieces aggregating the same measurement. On the outside faces two more pieces are wrung on, lapping half on the single piece and half on the built-up piece. The whole may be supported by any one of the pieces without falling apart. An indefinite number of combinations may be successively subjected to this test, which, as regards the accuracy of the pieces, is of course almost absolute.

Fig. 257 shows the way these gages are used in multiple for plug gages. The two outside pieces are lapped to a circle; the two wrung together will measure a half-inch hole. Any of the flat gages can be used between the outside pieces to make a gage for any size of hole desired. Fig. 258 again shows a one-inch snap gage with a built-up piece in it -0.5 plus 0.2 plus 0.050 plus 0.150 plus 0.100 .

Though the adhesion of these gages is the same as if they

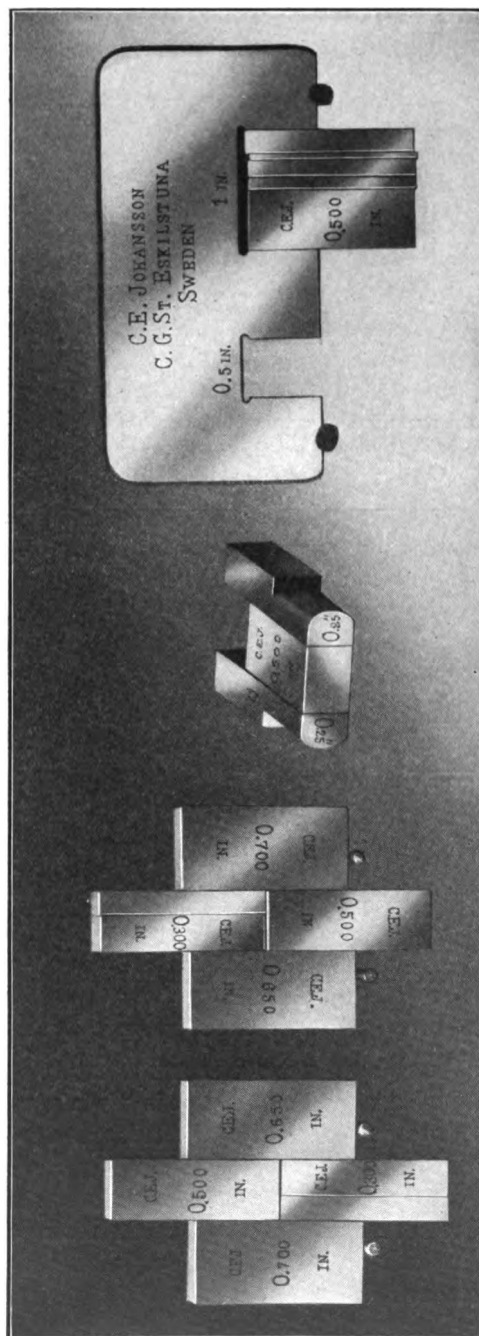


FIG. 256.—Two Views of the Five Pieces Wrung Together and Supported on Two Nails.

FIG. 257.—One-inch Built-up Gage.

FIG. 258.—Snap Gage With Built-up Gage.

were strongly magnetized, yet as a matter of fact they are not magnetized at all. They can only be held together when wrung so that the air is excluded. Yet the tension of pieces which have been wrung together is greater than that of air pressure, so that it is evident that some molecular attraction is combined with the force of the air pressure in holding them.

In brief, then, we are furnished with a complete set of gages enabling the mechanic to secure any size that he wants, including binary fractions; to check up his gages with other gages from the same set and to do much that has hitherto been possible only by use of measuring machines or micrometers.

The smallest increment is small enough for determination of not only limits but tolerances, and the gages would seem to furnish all needed means for determining working gages of any required degree of accuracy.

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